UNITED STATES NAVY

Office of Naval Research
European office, London

UNITED STATES Army

Research, Development and
Standardization Group-UK, London

First Tri-Service Workshop Review on private R&D in FSU

(Purchase Order # 68171-96-V-6306)

final report

21-25 September 1996

Moscow, Russia

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

SECTIONS OF THE COFERENCE. ТЕМАТИКА КОНФЕРЕНЦИИ

1. Surface Treatment, Properties Modification. Обработка поверхностей. Видоизменение характеристик.

a. Plasma Treatment. Плазменная обработка

Adam M. Gonopolsky. "Plasma-Test" JSC. Protective Coatings for Aircraft.

Adam M. Gonopolsky. "Plasma-Test" JSC. Plasma Treatment of Medical Waste.

Zeldin Yu.R., Maximov A.I. "Test" Co. Ltd. New Type of Reactors for fabric and Fibre Treatment.

Vursel Ph., Nasarov V., Plasma Treatment of Long Tubes.

Vursel Ph., Nasarov V., Plasma Treatment of Quartz Tubes.

Vursel Ph., Schmidel Ph., Pneumatic Classifier of Dispersed Materials.

Tyurin Yury, "INTERM" IA, Electric Friction Technology and Equipment for Strengthening and Sharpening of Agricultural and Mining Tools.

Tyurin Yury, "INTERM" IA, Technology and Equipment for Electrolytic-Plasma Quenching.

Puzraykov An, Puzraykov Al., Solovijev I., Polaykov V., Puchkov V., Gladkov V., Anikin P. SIE "Giperon". Mobile device for air-plasma spraying.

Puzraykov An., Puzraykov Al., Solovijev I., Polaykov V., Puchkov V., Gladkov V., Anikin P. SIE "Giperon".The development of technology and mobile equipment for air plasma are sharp black and colour metals.

Puzraykov Al., Solovijev I., Gurin V. SIE "Giperon".Drawing of protection-decorative covers on large-sized details and other enginnering.

Puzraykov An., Goncharevskiy A., Semenova S. SIE "Giperon". The system of automated designing plasma-sprayed tecnique protective coatings various functional purpose.

Goryunov V. "Delfin-TTT Ltd" Development of Mathematical Models for Geometrical Imitation of Thermally Sprayed Coatings.

Rogozhin V. "Plazma" Equipment Maintenance and the Undemolishing Method of High Precision Measuring ot the Coating's parameters ρ and π.

b. Laser Treatment. Лазерная обработка

Kikot V., Madgar An. "Delfin-TTT" Ltd. Equipment for Laser Treatment of Materials.

c. Explosion Treatment. Взрывная обработка

Tyurin Yury, "INTERM" IA, Plasma-Detonation Technology for Hardening of Working Surfaces of Machine Parts, Tools for Metal, Wood, Paper, Leather, Sugar Beet etc. Working

Blinov Yu., Kachanov B., Kogan B., Fedorova V. "AOK" Ltd. Pulse High Frequency Treatment (Technology and Equipment).

2. Laser Technologies. Лазерные технологии

a. High-Power Lasers. Высокомощные лазеры

b. Novel Technologies and Applications. Новейшие технологии и их применение

Therednichenko Ol., "Norma" Co.Ltd., Acoustooptical Filter for Tunable Lasers.

Therednichenko Ol., Lysoi B. "Norma" Co.Ltd., Acoustooptic Spectrophotometer for Vacuum Deposition Systems.

Abrosimov G., Buzhinskij Ol., Pulinets T., Skvortsova Al. “Line Co. Ltd. “ Diagnostic System Based on Copper Vapour Laser.

Grezev C., Zelenov E., Morozenkov A. Unique Desigh of Sungle-Mode CO2-Laser and Laser Technolodical Processes Development by the “Lasernye Komplexy“.

c. X-ray and Electronic Lasers. Рентгеновские и электронные лазеры

3. Semiconductors. Полупроводниковые материалы

a. Non-Traditional Semiconductors. Нетрадиционные полупроводники.

b. Thermoelectric Semiconductors. Термоэлектрические полупроводники.

c. Piezometallic Semiconductors. Пьезометаллические полупроводники.

4. Applied Physics. Прикладная физика

a. High-Temperature Superconductivity.
Высокотемпературная сверхпроводимость

b. Wave Propagation. ***Распространение волны.***

c. Surface Physics. ***Физика поверхностей.***

Dudar Ol. "Delfin-TTT" Ltd. Practice of Redesign of ex-Soviet Vacuum Machines by Using Imported Components and Subsystems.

Lohkov Yu., Moskalev I. Precision Grinking of the Solid by Pitch Polisher with Surface-Charged Abrasive.

Trofimenko V. "Line Company Ltd" High Speed Photography and Photonic Center.

Buzhinskij Ol., Tugarinov S., Azizov En., Trofimenko V., Naumenko N. "Line Company Ltd" Ion implantation pyrolytic heren nitride.

Buzhinskij Ol., Semenets Yu. "Line Company Ltd" Technology of In-Citu Deposition of Boron-Carbide Films from Carborane Precursor.

Buzhinskij Ol., Otrozhenko V., Virgiliev Yu. Line Company Ltd" Modified Graphite and Carbonic Fibre Materials.

APPLICATION NUMBER:

Adam M. Gonopolsky
General Director, Doctor of Sciences, Professor
6/8 Maroseyka Str.
Moscow 101000 Russia
PHONE: 095-236-32-51 **FAX:** 095-237-21-41
E-MAIL:
AFFILIATION: Joint-stock company "Plasma-Test"

Protective coating for aircraft

The progress in industrial production of lightweight, non-burning and strong cloth-based polymer composite materials, allowed to forego traditional metallic construction materials for fuselage, wings and other aircraft elements coating.

Because of this development in the last decades the production of aircraft with non-metallic cover was steeply growing. This is true for transport, passenger, sport as well as military aircraft.

Thus with a number of substantially positive qualities such as the lowering of fuel consumption rate, the increase of cargo carrying capacity etc, these aircraft have also acquired some shortcomings. For example, there appeared the problem of electrostatic charge evaculation from a flying aircraft, a steep lowering of aircraft coating resistance to lightning, an increase of the interference level on board equipment, especially in the area of outside radar stations action.

The aircraft with metallic fuselages didn't have those problems. The aircraft building companies have offered a number of local solutions to these problems. But there was no overall solution of all problems. The addition of metallic powder or carbon-carbonic fibres in the paint doesn't create a complete coating; the use of metallic foil or nets, as components of multilayer polymer composite material lowers their elasticity and prevents the forming of complex surface elements. Besides, because of the difference in the coefficient of thermal expansion the foil as well as the net are peeling off and destroy the material.

Attempts of gas-flame spraying have also been unsuccessful because of the surface charring and coating peel-off, and the traditionally used abrasive stream workover of the surface before spraying led to ruption of fibres of the clothbase.

The methods of vacuum spraying do not allow to create sufficiently thick and strong layer on the outer aircraft surface because of the prohibitive cost of the needed equipment.

As a result of research and testing a technological process free of the above mentioned shortcomings and securely solving all complex problems of non-metallic aircraft coating protection was created. The method's substance consists in the use of the traditional equipment for arc-metallization from aluminum wire

The speed of the electrical metallization gun relative movement vis-a-vis the surface creates a netlike coating with an electrical conductivity close to that of the metals.

The rate of coating is 30-40 gram per square meter.
Adhesive strength, erosion and corrosion resistance of the coating correspond to current aviation standards.

To create a micro relief on the sprayed surface in factory conditions there was used an evacuated cover layer of multilayered composite material during the polymerization process.

During repairs or by coverspraying at the airfield it is necessary to resort to a special abrasive stream preparation of the surface which is non-destructive to the clothbase.

The technology allows to spray-cover the assembled aircraft as well as its separate parts before assembly. It is possible to use this technology also during aircraft repairs for partial recons-truction of the coating.

The technology was tried out on:
- helicopters KA-50 and K-62 during testing, laboratory and flight tests at Kamov plant;
- SU-84 aircraft during laboratory testing at Sukhoi aircraft Construction Bureau;
- perspective models of flying objects at Zhukovski Central Aerohydrodynamics Institute.

All results of dynamic, vibration, adhesive, corrosion, erosion electrical and UHF testing were positive. The technology use is possible in factory and field conditions on serial equipment.

The spraying process capacity (on prepared aircraft) is 8 to 20 square meters per hour.

The technological process requires:
- a three-phase alternate power supply up to 50 kVt
- compressed air of 5 to 6 atmosphere pressure with a 1,5 to 2,5 cubic meters debit per minute.

The temperature of the environment during spraying should be above plus 5 C, the humidity not above 85 %.

PLASMA TREATMENT OF MEDICAL WASTE

Adam M. Gonopolsky, Doctor of Sciences, Professor

General Director, Joint-stock company "Plasma-Test"

Decontamination and destruction of medical waste, one of the most hazardous product of people's activity, have been thoroughly described [1] from medical and biological point of view, whereas the research on thermochemical aspects of the problem remains very much inadequate.

Typically, when testing microflore for its viability some characteristics are not given enough attention, such as heat-resistance of materials the outside or inside of which may contain microorganisms and/or conditions under which heat and mass transfer of various medical materials occurs given the high-temperature environment and transformation of one aggregative state to another. Mechanisms and thermal effects of chemical reactions in presence of technological materials have not been well-charackterized. To clarity sake, a simplified thermal (properties) scheme of chemical processing of infectious medical wastes is given below. For reasons of complexity of the process we have restricted ourselves to an idealized case leaving room for a range of assumptions. In general terms, the thermal treatment of waste includes evaporation of moisture, heating up to a fire point, incineration which results in residual solid ash subject to further remelting to produce slag. Normally, all the processes are accompanied by intense oxidation of components leading to transformation of treated materials chemical composition. For example, the incineration of organic fat with an excess oxygen forms dense and tight refractory surface layers with a low heat conductivity. From the standpoint of chemical kinetics it means that a kinetic process is abruptly slowing down when transforming into a diffusion one. A temperature inside biological objects having such surface layers may differ dramatically (by several hundreds degrees) from a temperature in the incineration zone. This is way biological materials when being treated not only have the ability to develop the environment beneficial for spore microorganisms recovery, but they also enable the vegetation of these microorganisms within a period of 20-22 days.

The refractory surface layers with a low heat conductivity may also be formed in an oxygen-containing atmosphere during heat treatment of metallic, ceramic, polimeric and other materials which are the basic part of medical wastes. To ensure destruction efficiency, the outer layer should have been removed. For this purpose, the temperature in the heat treatment zone is elevated to a level which enables the melting of outer layer and its removal as an ablative shall. Such temperatures are obtained when operating universal bloc-and module complexes developed by "Plasma-test" Joint-stock company which are currently in commercial use for hazardous medical waste treatment.

High-temperature plasma processing may be applied to various medical waste, including disposable syringes, needles, scalpels, blood transfusion devices, human blood and blood products, as well as infectious materials and pathological and anatomical wastes.

The products of treatment are reusable slag and metal.

Design and technology implemented in the complex resolve three main problems:

- sterility of the processed products;
- no risk of contamination for the staff and equipment;
- high protection against harmful components in effluent gases and liquid streams ejected out of the treatment area.

Pilot-plant testing has demonstrated the applicability of the complexes at pharmaceutical factories to destroy drugs unfit for consumption, at custom-offices for disposal of goods which are dangerous, infectious, substandard or prohibited from import into Russia. The complexes were judged to be capable of sanitary cleaning of areas during emergency situations and epidemics.

The unique property of the equipment lies in the fact that it provides a range of standard size complexes designed for different capacity: from 50 to 10,000 tons/year.

The complex is built as a set of standard 20ft containers comprising the following modules: 1. plasma furnace; 2. gas cooling system; 3. gas scrubber and water supply system; 4. waste loading unit; 5. power supply; 6. regeneration and gas supply; 7. technological module. The container-like arrangement of the modules makes it possible

to operate the complex both on the open concrete site and on industrial premises with a floor space up to 700 m^2 and a depth of the well of at least 6 m. Specific power consumption may vary depending on production rate in the range of 450 to 2800 kVt from the three-phase industrial network of alternating current (380V).

The major units are engineered for 10 years of continuous operation given appropriate operating conditions and due maintenance which implies replacement of electrodes twice a year and replacement of a furnace lining ones a year. Depending on production rate, the complex is served by the crew consisting of 9 to 15 engineers, technicians and workers.

The proposed technology is based on the sanitary regulations adopted in USA, France and other countries requiring that medical waste should not be treated or sorted manually.

The initial technological step is the on-site medical waste collecting. For this purpose hand carts with disposable plastic bags secured on them are kept in hospital departments, laboratories etc. The point where the open bag is secured on the cart is equipped with a pedal gear for opening a lid over the bag. The filled bags are delivered by the carts into a room, where the bags are sealed using standard hand-operated thermal welding devices installed along with cellular metal containers for bags transportation.

The second step is waste transportation to the treatment area. After being filled, the mobile containers for packed medical waste are wheeled out into a loading platform. A special truck is coming in at the platform. The vehicle is equipped with a handling mechanism through the use of which containers are lifted, arranged in two tiers and secured inside the metal, completely closed vehicle body. The routs of special trucking are agreed with traffic police and local sanitary inspectors.

The third technological stage is wastes plasma processing. This technology is based upon plasma arc melting of assorted medical wastes (toxic, infectious etc) in an airtight two-chamber caisson furnace with a molten bath and a heating beneath the crown of the furnace. The wastes on the surface of molten slag are exposed to air plasma jets from

linear sectional constant current plasma torches. Depending on production rate, the number of torches may vary from 1 to 5 with torches power in the range of 50 to 60 kwt.

Wastes packed and sealed in the disposable plastic bags are automatically fed through an elevating and transporting system equipped with a positional revolving loading device and a coaxial plasma torch which provides the equipment with a high-temperature gas protection against infection and contamination by wastes. Gas purifying system includes a bubbling chamber of the furnace and a system of high-temperature thermochemical catalytic filters of activated carbon-carbonic, basalt and mullit fibres. The system removes all harmful components and pollutants, including dioxins, in the off-gas stream to a level within regulated emission standard. There are no effluent liquids discharged. Provision has been made for off-gases heat regeneration and recycling. The equipment incorporates an automatic control system designed to contain any unforeseen off-design situation.

Environmental safety and sterility of the process is a subject of monitoring and control at any stage of the treatment.

Pilot-scale testing and finishing off the technology for medical, industrial and other wastes treatment were conducted on a specially built processing line which employed the plasma furnace and loading bloc along with other units. A comprehensive study and evaluation of the system has been done from both bacteriological and environmental point of view with participation of representatives from scientific and research institutes, such as the Institute for Prophylactic Toxicology and Disinfection and the Sysin Institute for Human Bionomics and Environmental Sanitation. Experts' evaluation and directions for use have been presented by the State Committee for Sanitary and Epidemic Inspection. Efforts to set up production of the systems have been included into the Governmental Program "Wastes". After the National Expert Committee of RF Ministry of Environmental Protection adopted a resolution in favour of the proposed technology, it was recommended for implementation in the city of Tolyatti identified as a proving ground for a federal project to recover medical waste. The Moscow

Government decided to install the complexes at some hospitals and ambulatory care facilities.

The joint-stock company "Plasma-test" provided all necessary technical documentation pertaining to the technology and set up production of the complexes for commercial use.

Results of research and development were summerized in the federal project to recover medical waste submitted to the Interdepartmental Committee on Public Health of RF Security Council. The project received a complete support and approval.

The project includes three major parts:

- to set up production of basic and auxiliary equipment;
- to organise the operation of equipment and transport;
- to elaborate standard and methodical documentation.

The project involves efforts of leading Russian institutions in the field of sanitation and epidemiology and of many engineering and industrial enterprises working for Department of Defence.

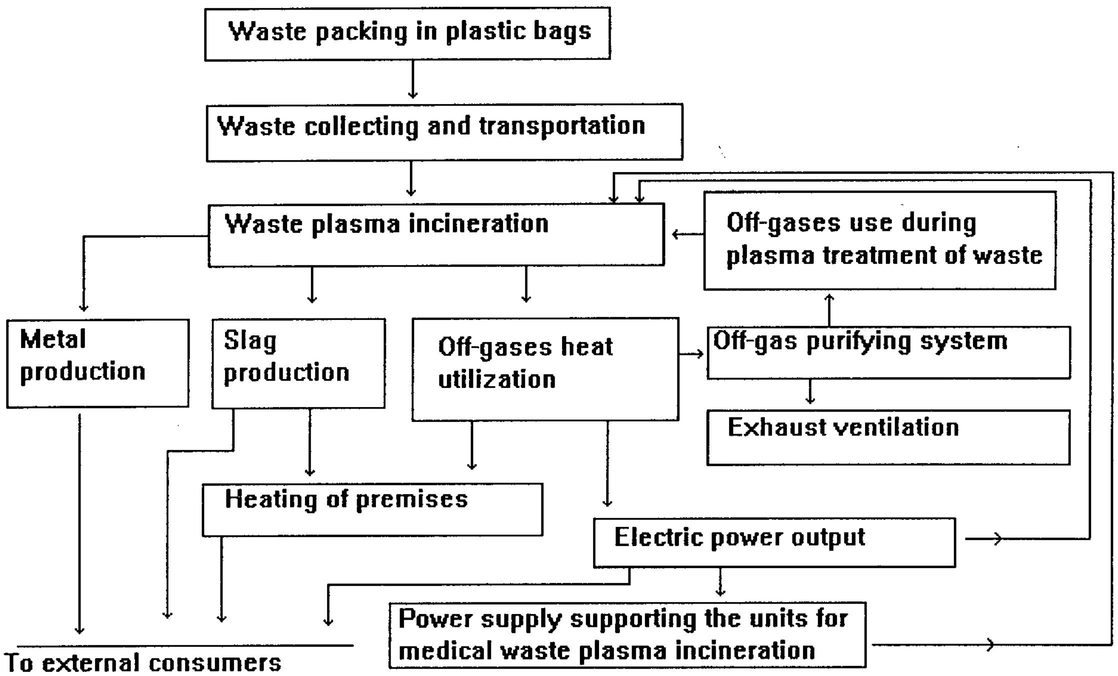
The project, if implemented, along with bloc-and module complexes applied for plasma treatment of hazardous medical and biological wastes would present a solution to a complicated environmental problem.

References:

1. Segal R.R., et al: "Development and Evaluation of a Method to Determine Indicator Microorganisms in Air Emissions and Residue from Medical Waste Incinerators", Journal of the Air Emissions and Residue from Medical Waste Incinerations", Journal of the Air and Waste Management Association, v.41, No.11,1991, p.p. 1454-1460.

2. Doucet P.E. "New Technologies for Medical Waste Destruction," Medical Market, No. 14 (2,1994), p.p. 62-65.

Technological Scheme of Plasma Application for Complex Treatment of Assorted Medical Waste



MAJOR CHARACTERISTICS OF STANDARD SIZE RANGE OF BLOC-AND MODULE UNIVERSAL EQUIPMENT FOR PLASMA TREATMENT OF CHEMICAL WEAPONS AND HAZARDOUS MEDICAL WASTES

Model No.	PT-1	PT-2	PT-3	PT-4	PT-5
Total power imput, kwt	460	800	1000	1800	2200
Productivity (kg/hour)	40-60	100-120	320-350	630-700	900-1000
Off-gases volume (Nm^3/h)	140-180	330-450	1015-1325	2000-2650	3000-4200
Slag output (kg/h)	5-10	15-25	40-50	80-100	120-150
Metal output (kg/h)	30-50	90-100	300-320	590-640	850-900
Number of containers	8	12	12	18	18
Occupied area (m^3)	410	530	530	700	700

NEW TYPE OF REACTORS FOR FABRIC AND FIBRE TREATMENT

Main questions of the design and operation modes optimisation

A.I.Maksimov, U.R.Zeldin

During last 10-15 years the interest of textile workers to the new method of textile materials treatment by low temperature plasma of glow discharge in vacuum (gas pressure about 100 Pa) grows. The specific technological features of this method of textile materials treatment are studied in details in laboratories [1, 2]. It is proved, that this method of treatment (textile workers named it plasma-chemical treatment - PChT) create some positive features of textile materials. It changes the molecular weight and chemical composition of the surface layer of fibres, makes it more hydrofilic and rough, which is favourable for carrying out many finishing processes:

- the adhesive strength of compounds of the synthetic webs with different coatings increases;
- the wettability and dyeability of natural and synthetic fibres increases (e.g. capillarity of the polyester fabrics increases from 40 to 200 mm).
- the yarn bond strength of natural fibres with each other and with synthetic fibres increases;
- the removing of oil and similar impurities from polyester fabrics increases in many times.

Plasma treatment is very effective when prosessing wool fibres. In this case the strength of roving and yarn in spinning increases on 30-40 p.c., which provide the decrease of the yarn breakage in spinning and weaving processes.

The capillarity of wool fabrics increases. That is why it is possible to prepare wool fabrics for printing without usage of chlorine as well as felting shrinking reduces in several times and resistance to abrasion increases. At the same time the fibre strength remaines practically unchanged, because only the surface layer of fibres which thickness is less then 1 mkm is subjected to considerable changes.

The glow discharge plasma treatment process is absolutely ecological. No waste products or harmful eradiation are being produced. But in many cases this method allows to simplify the technological process of fabric treatment.

The works on creating of equipment for plasma treatment of textile materials were carried out in several countries (Japan, Russia, Poland), but this equipment is not applied in textile

industry now. One of the reasons for this is the fact that this equipment occupy large floor area, while its output is very low, it is difficult for manufacturing and operating.

The low output and large overall dimentions of the equipment for plasma treatment, developed nowadays, are the result of its authors wish to provide continuous processing of textile materials. In this case the application of vacuum seals on inlet and outlet of the plasma treatment zones is necessary. These units are rather cumbersome and power-intensive and make the machine and its operation too expensive. The design of some of the developed machines provide the streight line movement of the material being treated in the plasma zone. This fact enlarges the plasma-treatment zone of the machine and limits its output.

The results of industrial application of different types of equipment for plasma treatment prove the following: the best design of the machines for textile webs plasma treatment is the design, providing rewinding of the web from one roll to the other, while both rolls are placed at the same vacuum zone as the plasma treatment zone, and the web is run through plasma in loops as it is done in many fabric dyeing machines. In this case the equipment is more compact and the treatment process cost decreases in several times.

The equipment for plasma treatment of fibres practically is not developed now, because all the works in this sphere are in the stage of laboratory researches. The existing metods provide the processing of the fibres in a rather heavy layer, which provide the efficiency, acceptably for industrial manufacturing. But at the same time only the surface part of the fibre layer is subjected to plasma treatment, that is why its effectiveness is considerably reduced.

The member of the stuff of the scientific-industrial accosiation "TEST" (Ivanovo, Russia) developed new design features, which allow to create machine МПХ-180, which has the following advantages in comparison with the already known machines:

- they are compact and it gives the possibility to make good use of the floor area;
- the construction simplicity and mechanization of all labour-consumming processes ease the operation and maintenance, providing conditions for reliable running of the equipment;
- the use of cloth rolls on the standard batches minimizes labour consumming characteristics of maintenance.

The offered technical developments permit to symplify considerably the structure of the equipment for plasma treatment of textile materials, so it may be lower in cost in 1,5 - 2 times then

the already known equipment of the same type while their output remaine equal.

Nowadays the experimental sample of the machine MПX-180 is manufactured at the Stock company "TSVET" (Dyeing and finishing equipment plant in Kostroma, Russia), production testing of which are preparing at present time. Now the work on developing of machine for plasma treating of spinning fibres is started .

The detailed information about MПX-180 is given in the applied booklet, the specific characteristics of the developed machine are described in patent materials and technical documents.

We suggest to the possible investors and customers:

a) sale of license for the use of patents and "know-how";

b) design documents (drawings and specifications for experimental samples);

c) an experimental sample (may be manufactured according to the standards of the customer).

Concluding of the agreement for cooperation in scientific recearches and design works and manufacturing of the equipment.

The spesific features of the plasma technology in processing of textile materials are described in details in the following reviews:

[1] Maksimov A. I, Gorberg B. L., Titov V. A.:The possibilities and problems of plasma treatment of fabrics and polymer materials.- M., "Tekstilnaya chimiya", N2, 1993, p. 101 - 118.

[2] Libonas U. U. and others: Application of glow the gischarge plasma in industry in textile industry. The information review.- M, TsNIITElegprom, 1987, iss. 1, p. 30

Ph.Vursel, V.Nasarov

PLASMA TREATMENT OF LONG TUBES

1. Problems of increasing of lifetime of long tubes (L>2m) appear on practice very often. They can be solved with plasma modification of tube's inner and external surfaces, film deposition, spraying of coating with ordered chemical and phase composition and microstructure.
2. Technology and equipment for plasma powder spraying of coatings on outer surface of long tubes are known. Technical difficulties are challenged by quality coating obtaining on inner serface of long tubes. They connected with:
   - nonuniform powder feeding on great distance from a feeder to a plasma torch,
   - complexity of organization of long tube rotation and plasma torch moving in it,
   - complexity of feeding of electricity, plasma gas and cooling water to a plasma torch.
3. We've designed:
   - a plasma torch of direct (in the case of metallic tube treatment) and indirect action with power ~ 15 kW;
   - a compact powder feeder of pneumatic type, situated near a plasma torch,
   - a machine-tool for simultinious treatment of both surfaces of tubes with L~ 2-3m and D ~80-150 mm from one side till another. A belt transmission is applied for rotating of a tube which is situated on rollers. A plasma torch and a compact powder feeder is moved by a special device on a bar.
   - new technical decisions for treatment of tubes with D >~200mm and L > 3m.

Coatings from Al_2O_3, TiO_2, MgO, TiN increase heat-wear-corrosion resistance. Coating thickness ~ 0,1 - 3 mm.

Ph.Vursel, V.Nasarov

PLASMA TREATMENT OF QUARTZ TUBES

I. Quartz tubes QT are applied as reactors in high temperature diffusive processes of power transistors and high density semiconductors manufacturing. They must be satisfied with the following criteria:

a/ deformation stability DS under operation temperature $T_0 \sim$ 1200 -1300 ^{0}C;

b/ thermostability TS under thermocycles from T_0 till 20-30^0;

c/ purity of reaction space PRS;

d/ absence of "memory".

II. a/DS is determined with a tube diameter D, **its** length L, character of loading and viscosity of material. The last depends on impurities in quartz glass (mainly sodium), their quantity and surface state (defects, and adsorbate comkposition). Continious crystall surface layer can rise DS.

b/ TS is determined with surface defects and impurities quantity.

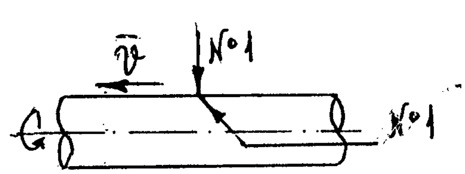
c/ PRS depends on diffusivity of impurities from outer space into reaction one through quartz glass. Rates of diffusivity in quartz glass of many elements including poisons for semiconductors are very high.

d/Process of adsorbtion-desorbtion of chemical compounds depends on the state of surface. Sometimes compounds adsorbed on one stage of semiconductors treatment desorb on another changing their charecteristics (effect of" memory").

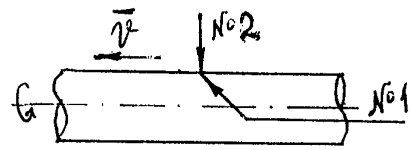
Thus, state, chemical and phase compositions and microstructure of surface layer influence on criteria listed above.

III. Experimental investigation and modelling of the following plasmachemical processes are fulfiled:

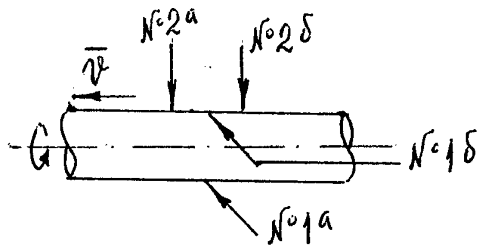
- removal of surface defect glass layer (P1);



- formation of coating and transitional layer glass-coating with desirable microstructure, chemical and phase composition(P2);



- implantation of crystal nucleous into surface layer with the next heat treatment of a tube.



It was determined that:

- in the P1 removal of surface layer ~ 100 mcm is a result of material evaporation, even glassy surface is formed, quantity of impurities in a surface layer decreased on some oders, mean concentration of Na^+ in a tube wall falls on 3-5 times, rate of adsorbtion is also decreased.
- in the P2 as a result of plasma powder spraying of alumina to quartz glass after P1 crystal layer of thermodynamic stable phase of ~α- Al_2O_3 (corundum) till 100mcm is formed. Transitional layer between coating and glass till 10 mcm from alumina-silicate glass serves as a barier for diffusion of poison impurities from outer space into reaction one.
- in the P3 implantation of crystal nucleous (Al_2O_3) into the purified by P1 glass surface layer till 10 mcm is realized. The next heat treatment results in formation of continious crystal layer with grain structure. As a result barier charecteristics and DS increase.

IV. On the base of investigated plasmachemical processes the following technologies PT were designed and applied in industry:

1/ PT1 of removal of defect layers from outer and inner surfaces of QT from one till another side with L till 2,5m and D~ 100-250 mm

2/PT2 including PT1 with semultinious plasma powder spraying of corundum coating on the outer serface of QT. L till 2,5m and D ~ 100-160 mm, the length of coating 1,6 m

3/PT3 including PT1 with semultinious implantation of crystal nucleous into outer surface . L till 3 m, D ~ 220-250 mm.

V. Complete set of equipment for realization of PT listed above is designed. It includes:

- a machine-tool for QT treatment from one side till another one;
- a plasma torch No1 of line scheme, power ~25 kW, velocity ~300m
- 2-jet plasma torch No2 with smal electrode erosion, power~ 25k velocity ~ 20 m/s;
- feed sources of electricity, gas and cooling water;
- powder feeder;
- powder classifier;
- UR -pyrometer for control of PT1

VI. Competition: after plasma treatment characteristics of QT become analoges as Heraus ones.

VII. Major advantagies:

- service durability and transistors quality increase,
- high productivity, reliability.

VIII. Cost analysis: processes are cheap and efficient. F.i., time of treatment of a QT ~ 45 min (L = 2,2m, D = 130mm, coating length 1,6 m).

Ph. Vursel, Ph. Schmidel

PNEUMATIC CLASSIFIER OF DISPERSED MATERIALS

Narrow fractions of powder materials are necessary f.i. for ceramic and quality glass productions, powder metallurgy, manufacture of adsorbents, powder spraying.

We designed a pneumatic classifier for simultanious devision of powder on some fractions.

An apparatus (fig.1) consists of the system of columns 1-4 with increasing diameter connected in series, a feeder 5, a cyclon 6 and systems of filters.

Performance data

Productivity. kg/h	10-200
Range of particle's sizes, mcm	15-800
Density of powder materials, kg/m^3	1500-12000
Quantity of fractions	2 - 6
Fraction's width per average fraction's particle size, %	10-20
Dimensions, m	1,6 x 0,5 x 2,8

Fractions of powder alumina are shown in fig.2
a - initial powder, b,c,d - fractions.

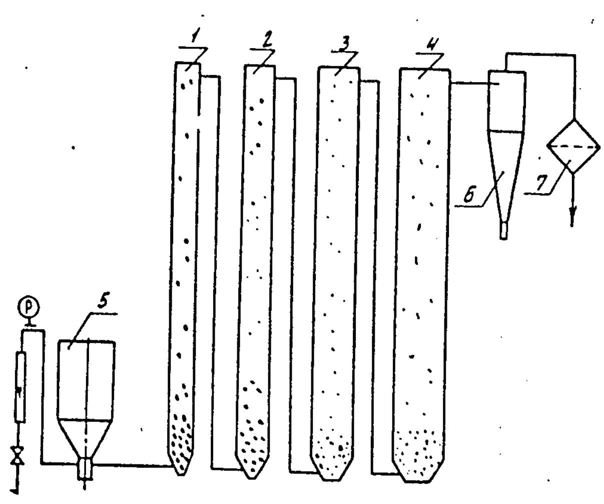


Fig 1

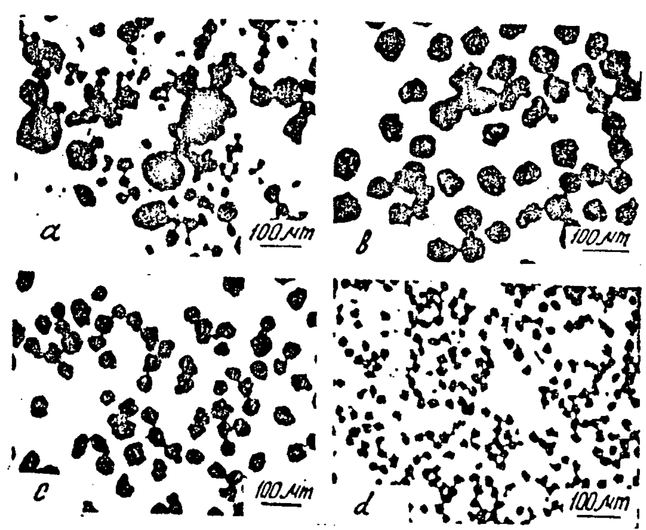


Fig 2

ELECTRIC FRICTION TECHNOLOGY AND EQUIPMENT FOR STRENGTHENING AND SHARPENING OF AGRICULTURAL AND MINING TOOLS

MO INTERM, E.O.Paton Electric Welding Institute, Kiev, Ukraine

Yu.Tyurin

Offered is the environmentally clean technology for strengthening agricultural and mining equipment tools, that ensures the 3 to 5 times improvement in their performance and a decrease in the material and power consumption.

The technology allows strengthening and/or sharpening of a particular surface (face) without heating of an entire tool, this being essential for soil-cutting tools (knives, colters, ploughs, harrow and sower disks, rippers, etc.), knives (mowers, fodder harvesting combines, straw cutters, etc.), fig.1.

Agricultural mining machine tool holders (0.65 % C) after electric-friction strengthening

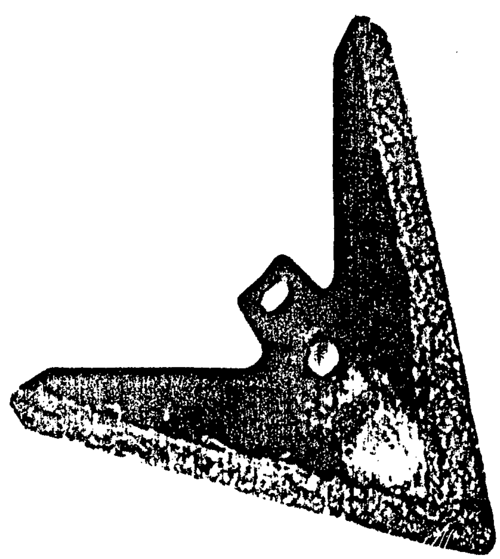


Fig.1.

The electric friction technologies are applied for strengthening and/or sharpening of wearing surfaces of medium-carbon and structural steels after volumetric heat hardening of a cutting blade.

Strengthening and sharpening are performed using electrodes in the form of a cast iron disk, which are rotated and displaced along the generating line of a workpiece surface, resulting in melting of the friction contact zone and in forming the micro-metallurgical pool, wherein the materials of a workpiece and the cast iron electrodes are mixed together.

After melting and melt alloying, a portion of the workpiece surface is rapidly cooled in water, then the next portion of a surface is melted, alloyed and cooled, etc.

For example, strengthening of the wearing surface of a disk harrow is provided by its engagement into a periphery of the cast iron electrode under the water layer. The electrode surface is pressed onto a workpiece, which is rotated about its axis and connected to an electric circuit, where a welding rectifyer serves as a power supply.

In this process only a small portion of the surface is heated and alloyed, all the rest (electrode, workpiece and technological structure) are cooled by water, this providing integrity of the volumetric properties of workpieces after preliminary heat hardening.

As shown by investigations and industrial testing, the efficiency of strengthening of pieces operating in an abrasive environment is 3 to 4 times higher, as compared to that provided by hard surfacing, at the lower (8-12 times) material and power consumption.

The typical microstructure of a strengthened layer comprises a surface molten layer up to 1.0 mm thick having hardness of 15-20 GPa, a layer of the rapidly quenched steel up to 3.0 mm thick with hardness of 9-11 GPa and quenched layer with hardness of 4-7 GPa, fig. 1.

The technology provides the high accuracy of location of the strengthened layer within the heat affected zone (100-300 microns). Here, hardness of the strengthened layer is close to that of a hard alloy, it being uniformly decreased from the max. value found at the surface down to the hardness of a steel.

The technological installation for electric-friction strengthening (sharpening) consists of a tank, a spindle unit, a disk electrode, a mechanical electrode drive and a start-control devices. A standard welding rectifyer is used as power supply.

Characteristics of hardened layer
in medium-carbon steel (C - 0,4 %)
after electric - friction quenching

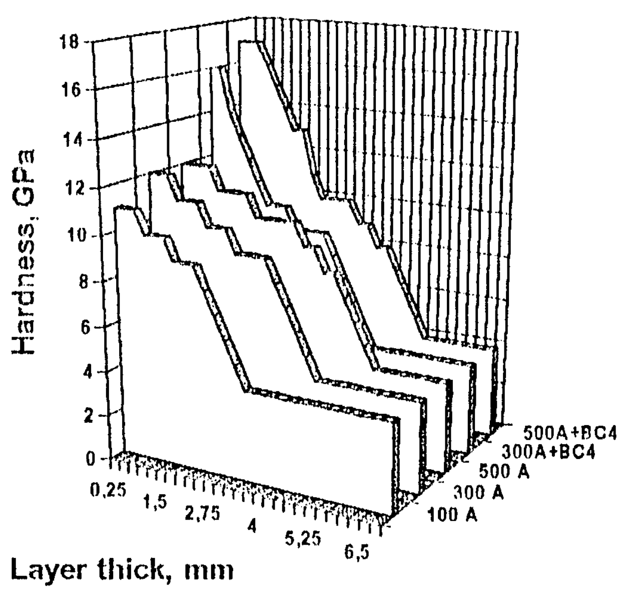


Fig.2.

According to a statement of the work agreed upon with a customer, the installation can be updated and the strengthening and/or sharpening operation mechanized.

TECHNOLOGY AND EQUIPMENT FOR ELECTROLYTIC-PLASMA QUENCHING

MO INTERM, E.O.Paton Electric Welding Institute, Kiev, Ukraine

Yu.Tyurin

The problem is that there are pieces operating under severe conditions, e.g. in underground rock mining, where abrasive wear of the working surfaces of machines is accompanied by alternating bending loads.

To strengthen such pieces there developed is a method of electrolytic-plasma quenching. This method is realized through heating and cooling of a wearing surface under a layer of the salt solution (electrolyte).

The energy for heating is evolved within a thin subsurface layer under the effect of electric current flowing through the electrolyte from an anode electrode to a cathode workpiece.

This provides the conditions for the formation of arc discharges in the vapour-gas layer at the workpiece surface, depending upon the value of electric potential.

The rates of heating and cooling of the workpiece surface can be controlled over the range of 50-400 degree/s through varying the density and the power of the arc discharges by regulating the value of voltage.

The distinctive feature of electrolytic-plasma hardening is heating by the electrolyte plasma (water being the plasma-forming environment) and cooling by the same electrolyte.

The method makes it possible to quench pieces so that the volume of hard regions at a surface makes up to 60 %, fig.1.

Characteristics of hardened layer in carbon steel

(HRC 35,C - 0,62-0,70 %; Mn- 0,90-1,20 %; Si- 1,20-1,60 %),

samples subjected to electrolytic-plasma

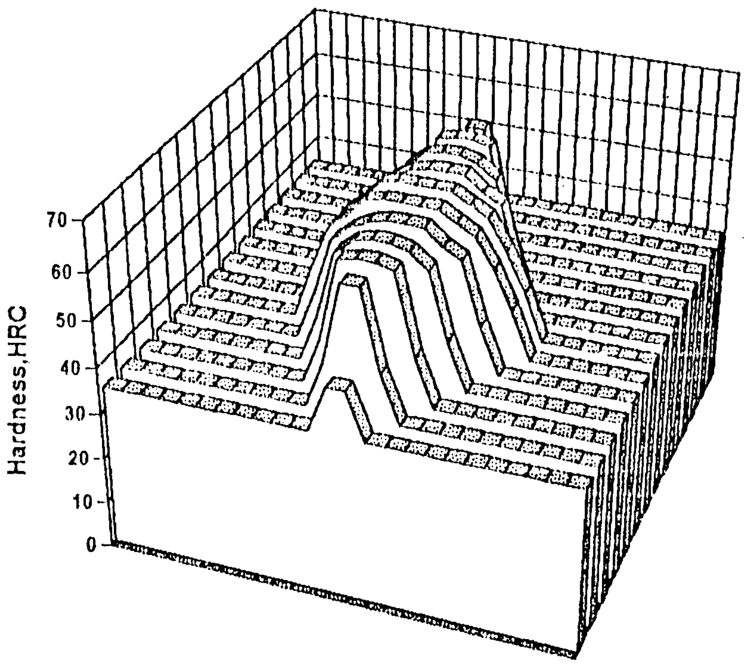


Fig. 1.

In this case the quenched regions work as hard macro inclusions, while plastic deformation of a piece occurs in the soft unquenched metal that surrounds these regions.

The method was tested on the industrial scale for hardening the medium-carbon steel plates used to manufacture flight conveyer chutes (0.35 % carbon), coal dressing machine screens (0.45 % carbon), agricultural machine disk harrows (0.65 % carbon), mining machine tool holders and air hammer picks. As shown by the tests, performance of the pieces after hardening increases 1.5...3 times.

Studies of surfaces of pieces after electrolytic-plasma quenching show that a finely dispersed structure forms in the regions directly subjected to heating, this structure consisting

of amorphous martensite having hardness of 4000-8000 MPa and bainite having hardness of 2200-2800 MPa.

The depth of the hardened layer can be from 0.5 to 10 mm, depending upon the treatment conditions, fig.2.

Characteristics of hardened layer in carbon steel
(C - 0,5; Mn - 0,5; Cr - 2,5 ; Ni -0,3; Mo -0,5; Si - 0,5)
after electrolytic-plasma quenching

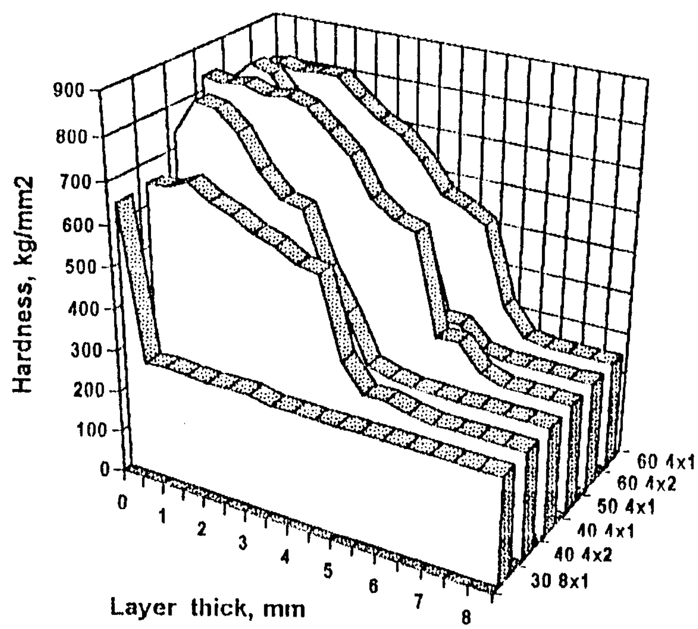


Fig.2.

Precipitation of hypoeutectoid ferrite within the material in the form of a fringe along the grain boundaries and refining of austenitic grains are observed in the HAZ with a distance from the electrolytic-plasma hardening region. Near a heat-hardened zone, ferrite is precipitated in the form of an intermittent fringes. Inside the grains there is the finely dispersed structure consisting of a sorbite-like component and an amorphous martensite, whose micro hardness varies from 2300 to 3900 MPa.

At the continuous moving nozzle for plasma heating on firm (HRC-55) the surfaces have become a layer the hardness increased on 30-40 % with a small zone of leave on a edge (boundary) will be formed, fig. 3.

Characteristics of hardened layer in carbon steel -HRC-55 after electrolytic-plasma quenching

C - 0,5; Mn - 0,5;
Cr - 2,5 ; Ni -0,3;
Mo -0,5; Si - 0,5

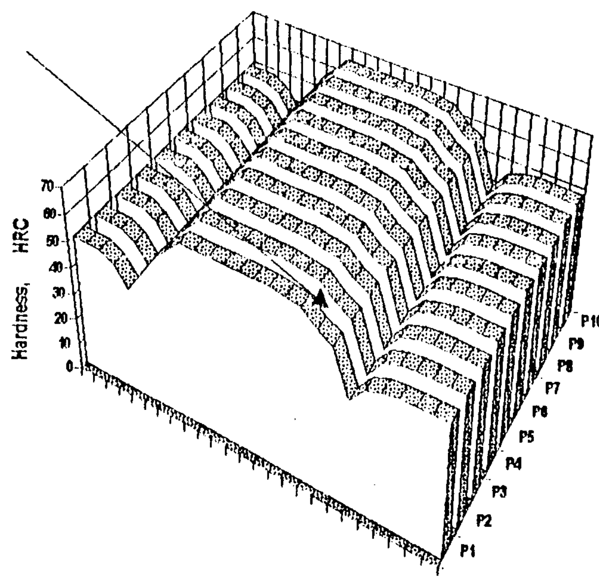


Fig. 3.

The technological equipment developed has the dimensions of fig.4. The rated power is 10-40 kW.

This equipment can be used to harden disk harrows, colters, ploughs, excavating machine teeth, chain conveyer sleeve faces, conveyer plates, coal dressing machine screens and other pieces.

The efficiency of electric power consumed for heating amounts to 70 % at the electric current density of 6...8 A/cm2.

The developed electrolytic-plasma quenching technology and equipment can be efficiently applied to harden the

worn-out surfaces of agricultural, mining, dressing and processing machine parts, fig. 5-6.

PROPOSAL ON STRENGTHENING OF THE WEARING SURFACES OF SHAFT, SOWS ROLLS AND DRAWING DIES IN METALLURGICAL PRODUCTION

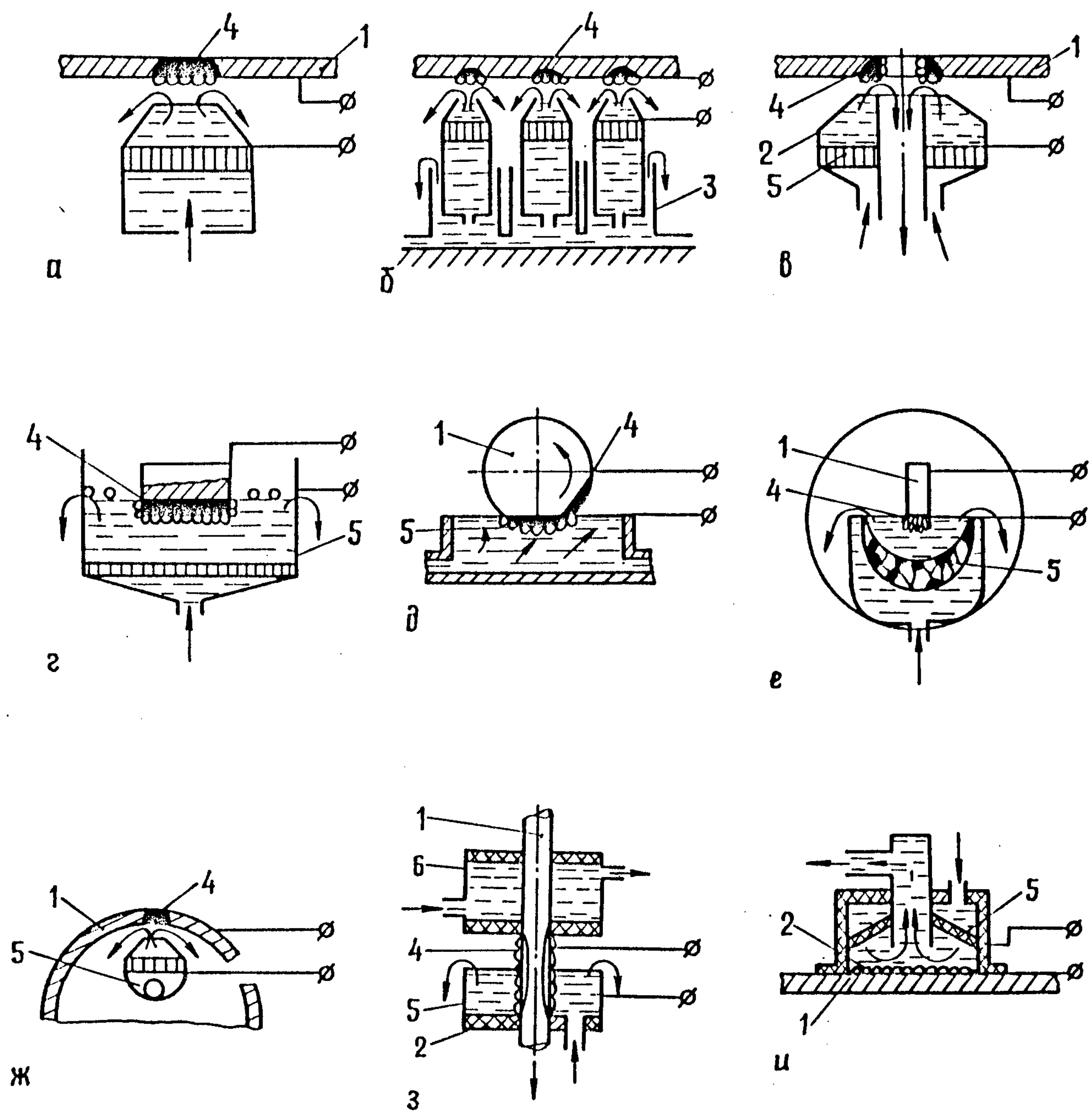


Fig.4.

The tests show that electrolytic-plasma hardening increases from 1.5 to 3 times wear resistance and strength of parts operating in abrasive environments and under alternating loads and vibrations.

Agricultural machine disk harrows (0.65 % carbon) after electrolytic-plasma technology

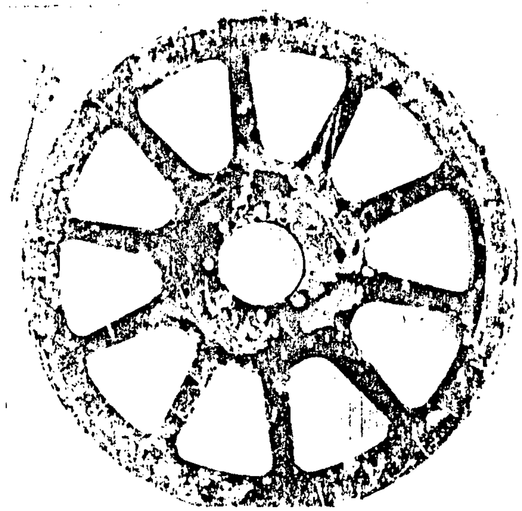


Fig.5.

Mining machine tool holders and air hammer picks after electrolytic-plasma technology

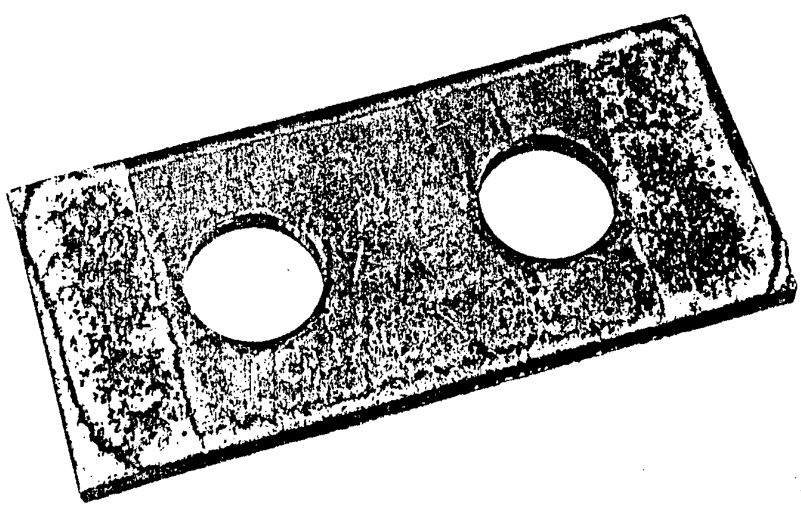


Fig.6.

EXTREME TECHNOLOGIES IN PRODUCTION OF BUILDING MATERIALS

G.G. Volokitin

Distinsive ability of technological progress of the second half of the XX century is the fact, that the capabilities of quasibalanced processes for further perfecting of process engineerings have appeared exhausted.

Practical achievement of extremes of pressure, temperature, speeds and other physical parameters has resulted in qualitatively new - strongly non-equilibrium processes.

Naturally, for a realization of non-equilibrium processes local concentration of energy is necessary which have, in particular (personally), laser ray and low-temperature plasma.

Controlled ad adjustable plasma heating allows to achieve effective mode of technological process, ensuring a maximum of useful output at minimum specific expences of materials and energy.

Besides, high-temperature heating by plasma flows creates conditions of strong non-balance, when at moderate middle-mass temperature particles of high energies participate in working process.

New knowledges of these processes have allowed the collective, headed by the author to create in area of building industry a number of in essence new process engineerings. The process engineerings have gained new base for development as applied sciences, such as plasma-and-chemistry, building materials.

At the moment on the basis of theoretical and applied researches the following process engineerings in building industry are realized:

plasma processing of building materials with the purpose of creation on their front face high-performance protective-decorative covers;

increase of a wear resistance of working bodies of machines;

salvaging of asbestoscontaining waste of industry;

renewalof refractory products from bacor for glass industry;

essential backlog on application low-temperature plasma in production of cement clincer is realised.

The main essential contribution of the author into develop-

ment of building materials and plasma-and-chemistry was:

theoretical generalization of researches outcomes in areas of plasma-and-chemistry and building materials with the purpose of creation of process of processing of building products with the help of low-temperature plasma;

generalized models of object and process of automated plasming of building materials of conglomerate type on the basis of various mineral matching are created;

techniques of temperature field calculation on depth of a treated product for two-phase case are developed at heating of its surface by plasma;

phase transformations, happening in a material under the operation of temperature fields, are investigated, temporary and thermal modes of processing are installed;

process engineerings and realizing their means, used in building industry are created.

Combination of executed researches and their realization in branch, under the judgement of Main technological management MPSM RSFSR, is gualified as theoretical generalization of researches in the field of building plasma technics and solution of a large technological problem.

The research activities have defined efficiency of use of plasma process engineerings and have planned perspective of development of new directions in building industry: production of mineral cotton wool and heat isolated products on its basis.

Existing melting aggregates and ways of processing of a melt in a filament do not allow to receive standard durable mineral cotton wool with $M_k > 2$ and module of viscosity M_v above 1,5, because of high viscosity and increased surface tension of a melt.

The application of high-enthalpy flows of plasma for melting of a blend provides high temperature of a melt with a module of an acidity more than 2, thus all processes of obtaining a mineral filament happen in one aggregate. The idea of glass production process transfer, in driven under an operation of mass forces a film of a melt by a natural image assumes the solution of a lot of problems of hydrodinamics and heat-mass exchange in difficalt heat-, chemical- and electrophysical conditions.

Name: Puzraykov Anatoliy Filippovich
Address:141814 Moscow a area,Dmitrovskiy a region,post office Orevo,
Scientific industrial enterprise "Giperon"
Phone: (095)587-38-03
Authorships:Puzraykov A.F.,Puzraykov A.A.,Solovijev I.N., ,Po-
laykov V.G.,Puchkov V.V.,Gladkov V.U.,Anikin P.V.

Mobile device for air-plasma spraying.

The essence of a method consists of use of thermal energy of a high-speed flow of a ionized gas, received in plasma generator. Powder material moves in a plasma jet, is melt and is transferred on a surface being a subject to restoration, where it have being cooled and forms cover.

Areas of application

Engineering - landing places; pairs of friction with increased tribotechnical properties and other.
Chemical industry - cartridge; screws; amalgamator's blades and etc.; cases of pumps; plungers a.o.
Auto-tractor engineering - landing places of shaft; levers; cams; crankpins; plugs of boxes of transfers; rings of synchronisers a.o.
Agriculture - shares; disks; scissors; shredders; levers; cams and etc.
Road building engineering - blades, dippers, teeths, drill bits.
The food-processing industry - meat process equipment
Construction - decorative, resistance to attack by corrosion covers sharp metals of various thickness and non-metal products.

Advantages

Mobility of installation;
Independence of operation;
Low cost price of processes of drawing of covers .

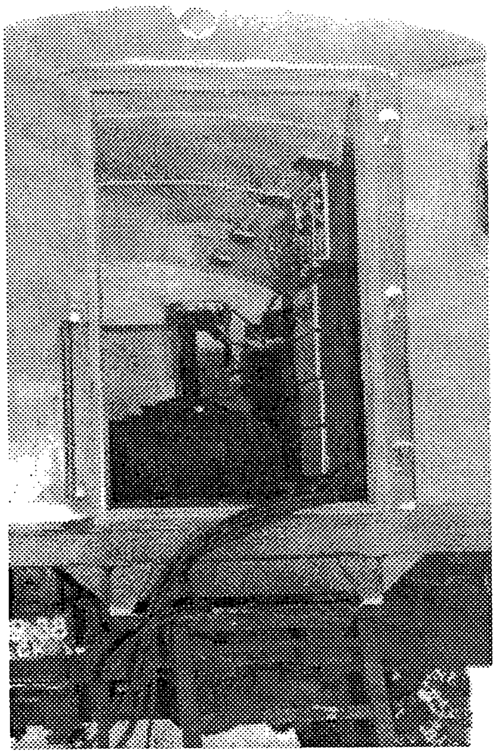
The competition Plasma spraying competes with Gas-plasma and detonation kinds of spraying

Methods application of coating	Thickness Mm	Strength Coupling, MPa	Output Kg / h	Cost of ispraying$
Plasma Ar-N air	0,1-10	20-50	5-7	0,1 0,04
Gas-flame	0,1-10	10-25	3-4	0,23
Metallisation	0,1-5	5-15	4-5	0,05
Detonation	0,05-0,5	75-100	0,9-1	0,75

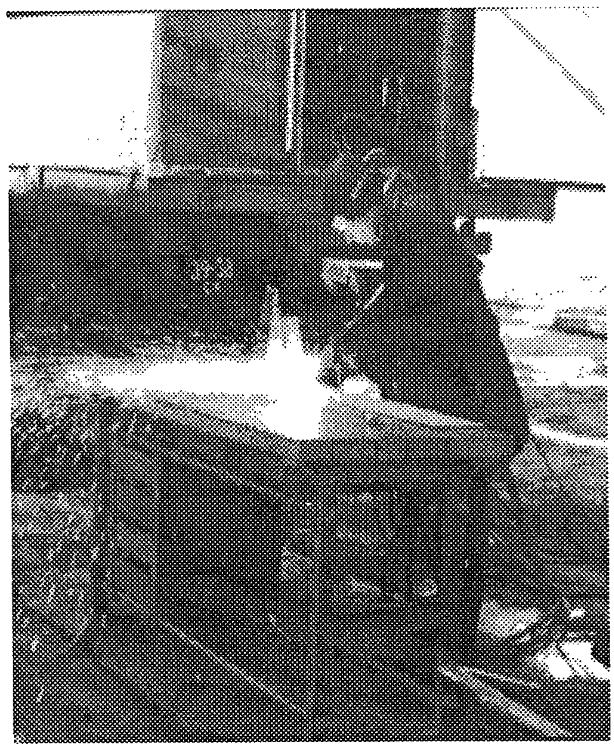
Some of characteristics

1. Capacity of installation - 40 or 80 kW,
2. Pressure of compressed air up to 6 MPa .,
3. Cooling of plasma generator by tap water with pressure not less than 3 MPa .
4. The installations can be completed by a computer control system.

Cost of development and manufacturing of a plant, including technology and training of staff of 35000 dollars USA



Mobile device for air-plasma spraying " Amur"



Process plasma spray

Name: Puzraykov Anatoliy Filippovich
Address:141814 Moscow a area,Dmitrovskiy a region,post office Orevo,
Scientific industrial enterprise "Giperon"
Phone: (095)587-38-03
Authorships:Puzraykov A.F.,Puzraykov A.A.,Solovijev I.N., ,Polaykov V.G.,Puchkov V.V.,Gladkov V.U.,Anikin P.V.,

The development of technology and mobile equipment for air plasma are sharp black and colour metals.

The essence of a method consists of use of thermal energy of a high-speed flow of a ionized gas, received in plasma generator.

The divice is mounted in covered biaxial trailer or on a chassis of automobiles ZIL, KAMAZ, URAL with a closed system of water-cooling and compressor with a system of air-cleaner.

Purpose:

Semi-automatic and hand-operated air-plasma is sharp carbon and high-alloying steels, cast irons, colour metals and their alloys in field conditions.

The area of application:

The salvaging of products and objects, removable from operation in breakage, separated sharp designs from different kinds of metals.

The advantages in comparison with a alternate equipment are sharp:

- High efficiency and the low cost are sharp;
- Simplicity of operation and reliability of installation;
- For work of device a diesel-generator the pressure(vol tage) 380 in And capacity of 80 kW AND compressed air as a working gas is necessary;
- Absence of the requirements to quality of preparation of a surface and accuracy of set-up;
- Minimum thermal effect on a metal edge and thermal deformations in cutted out details.-

The comparative characteristics of various ways are sharp are llisted in table for carbon have become thickness of 20 mm.

The ways are sharp	Productivity m / min	Cost of cutting, $
Plasma-air	***2,7***	***0,01***
Acetylene-oxide	0,35	0,13
Kerosen-oxide	0,72	0,2

Main characteristics:

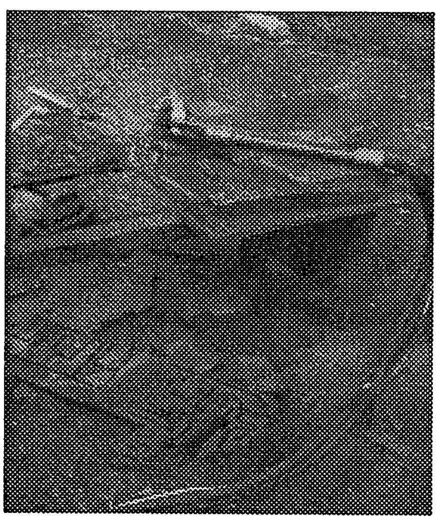
- Thickness of cutting materials up to 220 mm;
- Speed of sharping of carbon steel with thickness by 20mm -160 m/ h;

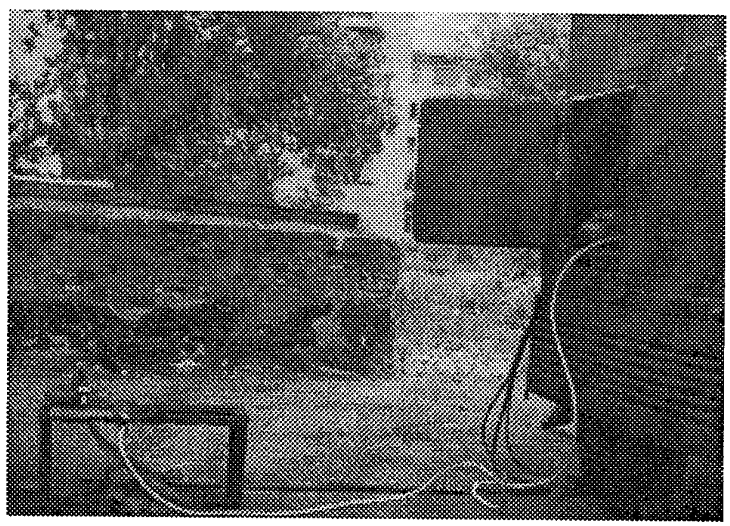
- Distance from device up to a place of sharping is 10-12 m.
- Capacity of device is up to 40 kW
- Pressure of compressed air is up to 6

Completeness of device:

- Control panel with a block of the power supply;
- Cutting plasma generator;
- Block of independent cooling;
- Compressor with a system air-cleaner.

Cost of development and manufacturing of a plant, including technology and training of staff of 23000 dollars USA





Mobile device for air-plasma are sharp black and colour metals.

Name: Puzraykov Anatoliy Filippovich
Address:141814 Moscow a area,Dmitrovskiy a region,post office Orevo,
Scientific industrial enterprise "Giperon"
Phone: (095)587-38-03 Fax:
Authorships:Puzraykov A.A.,Solovijev I.N., , Gurin V. N.

Drawing of protection-decorative covers on large-sized details and other engineering

At present as protective of resistance to attack by corro sion covers the covers from a zinc, aluminium and their compo sitions , put on a surface of details , gas-flame and plasma methods are applied, but polymer covers are put by methods of electrostatic and tribostatic. Unfortunately these methods do not satisfy arising needs(requirements) in the field of drawing of protection-decorative covers because of complexity of technological process and equipment. So, for drawing of protection-decorative cover by the method of tribostatic a following structure of the equipment is required:
- air-hole cabinet (box) with separator for recuperation and vacuum sweeper for the tax small-sized fractions by cost of2000 $.;
- Tribostatic installation for drawing, consisting of dispergator and feeder, cost 400 $;
-- Furnace with volume 2 m ^{3} (compound) and temperature 200 °C

About я0With the two-section cost 4000 r.Г.

Cost 1 m ^{2} of Cover, drawed by these method, makes 12-15$., not including the cost of a spent material.
Feature of a given method is subsequent polymerisation of cover in a furnace, that is connected to significant difficulties at processing of large dimensional products. The new technology is submitted by GAS-THERMIC METHOD of drawing of covers.
The essence of method consists of use of thermal energy of a high-speed flow of a ionized gas, received in plasma genera tor. Powder material moves in a plasma jet, melt and is transferred on a surface, being a subject to protection, where have been cooling forms cover.
The structure of the equipment for gas-thermic method include of installation plasma spraying, including in self:
- Block of the power supply from industry network;
- Control panel;
- feeder;
- dispergation block.

For work of installation the electric power, the water and compressed air are required only.

Methods application of coating	Thickness Mm	Strength Coupling, MPa	Output Kg / h	Cost of ispraying$
Plasma Ar-N air	0,1-10	20-50	5-7	0,1 0,04
Gas-flame	0,1-10	10-25	3-4	0,23
Metallisation	0,1-5	5-15	4-5	0,05
Detonation	0,05-0,5	75-100	0,9-1	0,75

The tabulated data on the cost of spraying are indicated for spraying of cover by the size 10 e10 mm by thickness of 0,1 mm without the account(record-keeping) of the cost of a material.

Cost of polymer sheeting such the size makes:
- Drawing by electro - and tribostatic - 0.15$;
- Put by gas-thermic method -0.07$.

Cost of drawing material is 6-12.5$ with NDS

Charge of a material on 1/ m^2 depend on density and thickness of cover, but not more than 0,5 KGs / m^2

Under orders of the customer the drawing of protection covers by air plasma spraying can be realised in three variants:

a) Stationary variant: capacity of installation - 40 or 80 kW, pressure of compressed air up to 6 atm., cooling plasma generator by a tap water with pressure not less than 3 вhm. The ins tallations can be completed by a computer control system.

b) The mobile variant is installed in a covered body on the basis of a automobile of a series CAMAS or URAL and consists of mobile diesel-power station of a type ESD-60 vs, compressor with a system of air-cleaner a type SЋ-62 A or SЋ-243-1, block of independent cooling (BIC), the installations correspond to characteristics of stationary variant, contain managing and communication systems. ,) portable variant: consumed capacity not more than 6,5 kW, feed(meal) from a single-phase network by
a pressure(voltage) 220 V, weight of installation not more than 40 KGs.

The simplicity, convenience, reliability, mobility and safety of these installations do(make) their irreplaceable in non-productive conditions. As stationary, as mobile variants at will of the customer can be completed additional plasma genera tion for spraying of hardening covers and are sharp of concrete products.

<u>Application:</u>

Agriculture - complexes

A chemical industry - tanks

Road construction - bridges, protection and other.

Technology reception of covers from mullite and spinel du ring drawing of silica oxide Si with the additives of powders of the aluminium .

The essence of a method cover is put:
- Air plasma from a dry mix of powders with subsequent, its(his) heat treatment. (thermal processing of details with cover in process of operation) is admitted(allowed) ;
- From slip (solution liquid of natrium glass and mix of powders like as with drawing by a plasma) with subsequent it(him) thermal treatment for reception of ceramics.

<u>Application:</u>

The covers can be applied to protection of de tails from constructional steels at operation them in oxidising environment with temperature up to 1500 ° C and speed of a gas flow up to 50 m / sek with.

<u>Concurention:</u>

Permits to replace covers from more expensive oxide of the aluminium on less responsible details and to increase their term of operation in 5 and more time.

Name: Puzraykov Anatoliy Filippovich
Address:141814 Moscow a area,Dmitrovskiy a region,post office
Orevo, Scientific industrial enterprise "Giperon"
Phone: (095)587-38-03
Authorships:Puzraykov A.F.,Goncharevskiy A.V.,Semenova S.A.,

THE SYSTEM OF AUTOMATED DESIGNING PLASMA-SPRAYED TECNIQUE PROTECTIVE COATINGS VARIOUS FUNCTIONAL PURPOSE

The development of a modern engineering is characterized further intensification of modes of operations of machines and vehicles, increase of the operational characteristics of details of machines, such as working temperature, pressure, strength and ect. One of ways of the decision of a given problem is drawing of special covers on constructional materials. In conditions of variety of methods of drawing of covers, equipment for realization of process and wide nomenclature of materials there are difficulties with justified(reasonable) choice of a kind and way of drawing of cover depending on the operational requirements to a detail with cover, as well as in view of efficiency of process. Before the technologist is a problem of choice of the most optimum technological process in view of a complex of the factors, determining process of drawing of cover.

The similar problems are decided with use of methods many factor of optimization, as the fulfilment of the majority of properties conflicts with one another. From the conducted analysis of the main requirements to materials and technological processes it is visible, that only a insignificant part of the requirements (temperature melting, hardness, module of elasticity, the mechanical strength and other) are determined, that is given particular number, while other are set, as a rule, non clear by sets of the requirements.

Therefore at designing it is necessary to use the theory non clear of sets, that will allow to enter into mathematical models of problems of optimum designing determined and non clear of the requirement in the similar form, and at many factors of optimization To receive effective compromise of the decision.

For maintenance of effective work of the technologists and for decrease(reduction) of losses from acceptance of the unreasonable decisions in development of technological processes in a number of branches of manufacture resort to creation of systems of automated designing(SAD). So in the beginning of 80-x years work on creation SAD of technological processes of hot processing of modern alloys, including in self SAD of welding, soldering, thermal spray of drawing of covers began.

In given work processing amplified(strengthened) to new information technology of knowledge is represented intelligent SAD of covers,. Unlike being present systems of designing the structure ISAD enters means of systems of processing of knowledge. Systems of processing of knowledge management including in self of bases of knowledge, the strategy of search, gears of a conclusion and other are programm systems, supplied by special tool of processing of information,. Such means can be used with usual programm modules SAD.

The given system is a dialogue system of designing, in which the technologist decides design problems together with A COMPUTER, using diverse design knowledge of the experts, submitted in a computer system. Opened integrated intelligent environment of support of acceptance of the decisions is organized as opened, non-uniform, integrated intelligent system with a variable structure. The basis of a system is made by(with) five equivalent modules (fig. 1):

- The system nucleus, which executes general management of work of the other modules, exchange by managing data, will organize exchange by the information between modules (fig. 2). The system nucleus is a opened software, enabling to connect unlimited number of additional modules;

СТРУКТУРНАЯ СХЕМА ОТКРЫТОЙ ИНТЕГРИРОВАННОЙ ИНТЕЛЕКТУАЛЬНОЙ СИСТЕМЫ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПРИ ПРОЕКТИРОВАНИИ ПОКРЫТИЙ

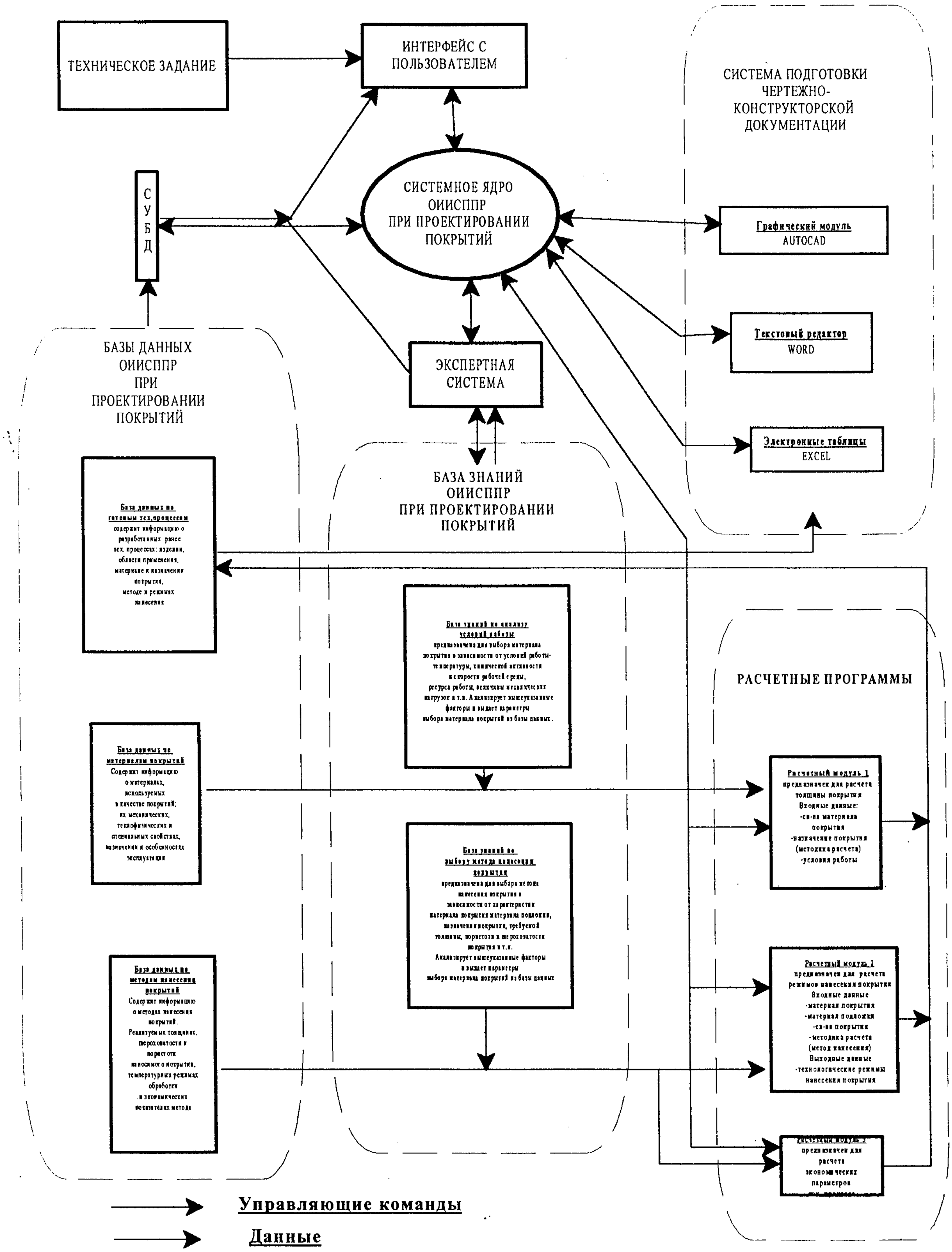


Рис. I.

Схема организации взаимодействия и обмена данными между базой знаний, базой данных и расчетными частями ОИИСППР при проектировании покрытий

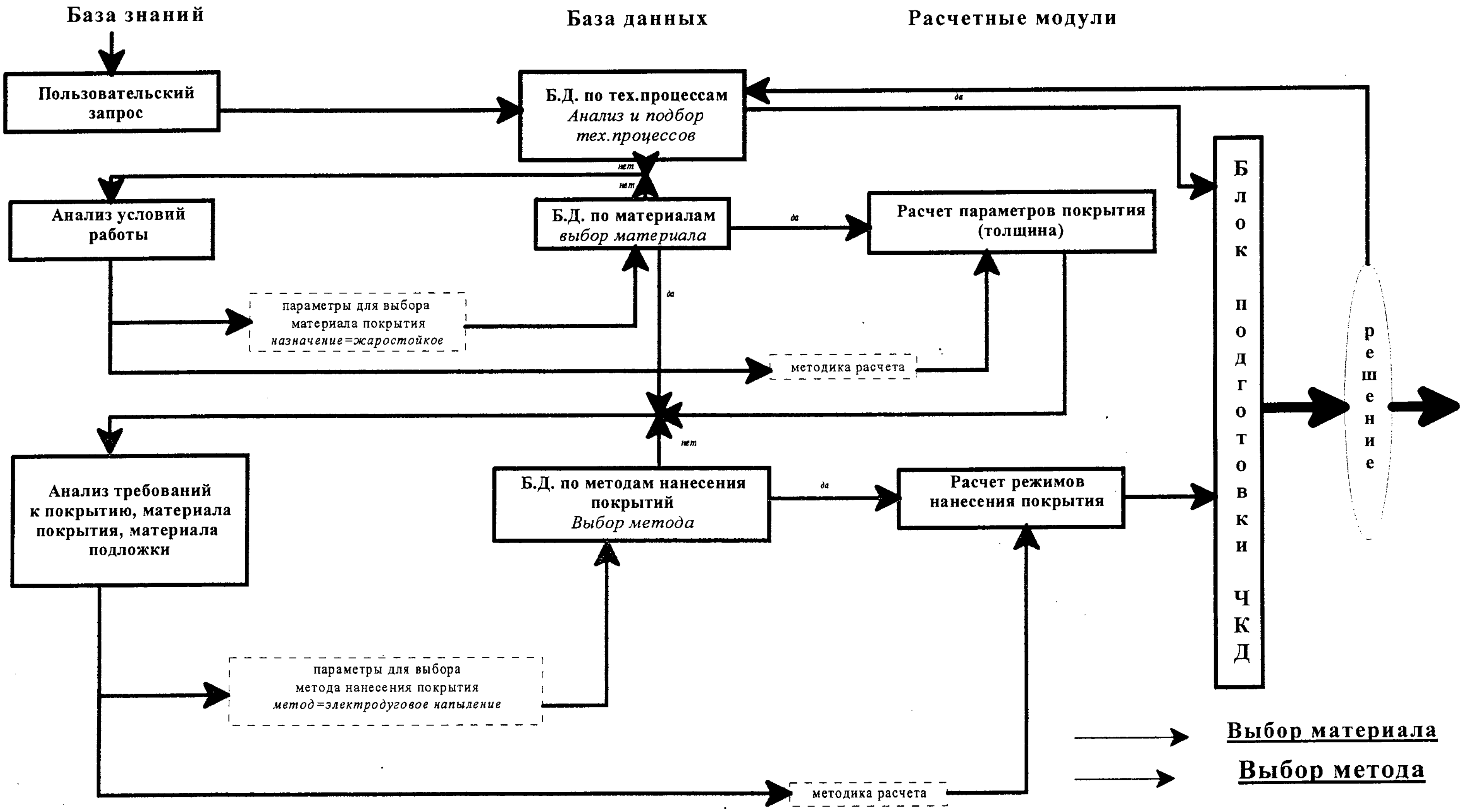


Рис. 2.

- The expert system executes processing of the information, contained in databases, will realize a interface with the user by work with bases of knowledge. The expert system permits to create new bases of knowledge, to supplement by the information already created bases;
- The control system of databases DELPHI will organize processing of databases and supports a interface with the user by work with databases;
- The settlement part contains settlement modules, intended
For account of parameters of cover, modes of technological process, account of economic parameters and ect.;
- Block of preparation of the чертежно-design documentation, including in self Autocad - for design study of a product of preparation drawing of the documentation, Word - text editor for preparation and processing of the textual documents, Excel - electronic tables for processing of the tabulared information.
Intelligent SAD contains following bases of knowledge and database:
- The base of knowledge under the analysis of conditions of work is intended for choice of a material of cover depending on conditions of work (temperature, chemical activity of working environment, resource of work, size of mechanical loads and ect.). Analyzes the above-stated factors and gives parameters of choice of a material of covers from a database;
- The base of knowledge at the choice of a method of drawing of cover is intended for choice of a method depending on the characteristics of a material of cover, material of a substrate, purpose of cover, of required thickness, porosity and roughness of cover and ect. Analyzes the above-stated factors and gives parameters of choice of a material of covers from a database;
- The database on methods of drawing of covers contains the information on sold thickness of covers at a given method,porosity and roughness of cover, temperature modes of processing and economic parameters of a method;
- The database on ready technological processes contains the information on processes developed earlier by technological, product, area of application, material and purpose of cover, method and mode of drawing;
- The database on materials contains the information on materials, their mechanical, heat physics and special properties, purpose and features of operation.
The settlement module contains the applied programs, created on the basis of mathematical models of physical processes. The programs "METHOD", "FUNC","TEOM" assist to choose a technological method of drawing of covers, the program "CHOICE" will realize(sell) choice of a material of cover from conditions of operation, "COM" - designs composition a material, "GRAD""WIBRO" "IMPULS" - technologist regimes of drawing of covers, "WORK" - for valuation of serviceability of covers.
Work on filling of a system by the information of the qualified experts, as well as creation of mathematical models and applied programs for creation of the complex approach to the decision of a problem of choice of technological process of drawing of covers of various functional purpose are at present carried out(conducted).
Thus, the application of a system of automated designing of covers in15-30 time reduces terms of designing and development plasma spray processes of details with covers, improves quality of covers at the expense of reduction of quantity of errors at designing.

Development of Mathematical Models for Geometrical Imitation of Thermally Sprayed Coatings

Vladimir V. Goryunov

"DELFIN-TTT Ltd" Engineering Company
Sumgaitskaya str. 13/1, P.O.Box 1615,
Cherkassy-10, Ukraine 257010
tel./fax 0472-669402, tel.0472-651513

1. Introduction.

Mathematical Models Developments for the imitation of geometrical structures in thermally sprayed coatings become an important part of the company's engineering activity of "DELFIN-TTT Ltd" in the area of Thermal Spraying Technology and Equipment. Conceptually, this is due to a forecasting ability of the models that permits to make coatings of new properties, where porosity is advantageous.

2. Results of the First Stage of Developments.

Main imitation principles of a coating forming process were developed with the help of mathematical modelling. In this regard, as a basic condition, it was employed that during an optimal mode of thermal spraying a coating is being formed as a result of casual laying of particles. This is characterized by individual transition from a solid state to a liquid one accompanied by deformation and particle splashless spreading over the surface. Some initial points for the modelling were set forth, such as a degree of particles' after-impact-deformation, particle speed, particle size before impact, particle percentage of different materials in spraying mixture, spraying period of time, presence of discontinuities on surface, spraying material expenditure. A mathematical modelling was provided for a simple case to get a coating model and study geometrical peculiarities of porous space, porosity, specific surface, interaction of particles and their distribution in case of two different materials in the spraying mixture.

3. Conclusions and proposals.

On the first stage of the developments it was proved that:

a) the offered mathematical modelling makes possible the investigation and prediction of some geometrical structures, which are unlikely to be investigated differently.

b) it is evident, that the methodology in question has a perspective for future developments.

c) with the help of this modelling, now it is possible to predict the introduction of new composite coatings and create new perspectives for the development of the thermal spraying technology. To substitute "natural" investigation by modelling allows to have a shorten and less cost-effective lead-time for any new applications of the technology.

d) further development of the modelling techniques is the next second step which is necessary to do.

e) taking the given experience as a basis, it is offered to design a programme package for the computer-aided modelling with a visual simulation of coating models, including a vapour space geometry in different sections, particles distribution of one material in a coating, when a composite mixture is sprayed, surface roughness of coatings, and with an automatic computation of porosity, specific surface and other geometrical parameters of coatings. The second stage has to be finished by the design of programme packages for sale. The development of a range of models of different approximation degrees will give some real solutions for the customers' problems of design and production of various thermally sprayed coatings, including the composite ones.

Equipment Maintenance and The Undemolishing Method of high precision measuring of the coating's parameters ρ and π.

Rogozhin V.M. ("Plazma")

Abstract.

Method of determining of the 5 parameters of density and porosity of gas-thermal coatings had been investigated. Conditions of measurings had been investigated. Conditions of measurings had been determined and fixed. Necessary equipment maintenance is created. The accuracy of the measurings method which characterise itself by the relative error of $\pm 0,5\%$ for two of the measured parameters, is ascertained. Formulas for the calculation of meanings and for their accuracy's evaluation for three determined parameters more are obtained. The dependence which ascertains the correlation between the coating's density, its porosity and the density of the coating's material, which is determined by the known pycnometric method is found.

The Elaborated method allows to give a quantitative evaluation of stability and quality of worked-out technologies, to evaluate the influence of variating factors of technological processes strictly.

Technical Description.

New technologies of obtaining of the gas-thermal coatings revealed the problem of evaluation of the coatings` quality, i.e. the ascertaining of the quantitative measure of its` properties. The analysis of the known methods for determining of the coatings` properties demonstrated that there is the only method of tests exists, which accuracy is ascertained. The method is based on use of the hydrostatic force of pushing out in combination with the preliminary vacuum saturation of the researching coating by liquid. Fixation of the measuring conditions, realising the ascertained accuracy of the method, is reached at the expense of use of the elaborated plant. (the scheme and the photograph of the plant is presented on pic.1 and pic.2). The plant's dimensions are 1000 × 1000 × 600. Its weight - 50 kg.

The elaborated method of determining of parameters of density and porosity of the gas-thermal coatings is the undemolishing method of tests and admits the repeated measurings of the searching parameters. In this case the possibility to evaluate the accuracy of the tests` method with the setting reliability exists. It is ascertained that as for the parameters ρ and Π_0 the accuracy of the elaborated method is determined by the variation coefficient $\pm 0{,}5$ per cent on the 90 percentage of the reliability. The method allows to obtain in obvious form the quantitative evaluation of the new technologies` stability, the influence of newly introducing equipment, to evaluate the relative influence of the variating factors of technological processes strictly.

The results of investigations had been reported at the scientific conferences, they are published at the academic magazines. [illegible] Method had passed the approbation at the undertakings of various branches of Russia's industry, and also in a number of the higher educational establishments of the country. The complete set of technical documentation had been elaborated. The experimental samples of plants had been produced.

1. Surface Treatment, Properties Modification.
Обработка поверхностей. Видоизменение характеристик.

b. Laser Treatment.
Лазерная обработка

Equipment for Laser Treatment of Materials

Victor I. Kikot, Andrew V. Madgar

"DELFIN-TTT Ltd" Engineering Company
Sumgaitskaya str. 13/1, P.O.Box 1615,
Cherkassy-10, Ukraine 257010
tel./fax 0472-669402, tel.0472-651513

The employment of Laser Emission in industry shows promise, particularly, in treatment technologies for different materials because of some reasons, like: there is highly-dense energy in a laser beam that is comparable to the density of nuclear explosure energy; luminous energy concentration is available upon a very tiny surface; the directed energy is easy to control. Such characteristics of laser emission allow to design laser machines of unique functions. To get similar characteristics by other physical principles is either impossible or unprofitable.

At the present moment, it is beyond any doubt that laser machines have to be used for precision welding, thermal treatment, and for high precision cutting of materials that are different in their physical nature, including refractory materials. Customers of our laser machines are among those who:

- make pieces by spacing and cutting them out of sheet or multilayer materials;
- manufacture photomasks, stencils, profile templates or gauges;
- produce different cutting tools (i.e. circular saws, mills, etc.), elements of code locks, or other pieces of unlike shapes, where it is very cost-effective to use stamps or electoroerosion machines;
- engrave and mark measuring tools (slide callipers, rules, etc.), plates or labels;
- engrave bijouterie, souvenirs, etc.

Due to the activity of private business, a demand for laser machines under the situation of economical crisis is enough to promote and help further developing of laser treatment techniques for numerous materials.

In our company solid-state pulse lasers were designed in 4 options with YAG-Nd3+ active elements of the 1.06 μ wave length

and a power of up to 300 MW/cm^2. At the same time, a shape, duration, pulse period-to-pulse duration ratio, and pumping pulse frequency were optimized to achieve better interaction of laser emission with materials. These parameters are supported by pulse power sources that were also developed by our engineers. As a result, newly designed laser can cut steel of the 6-8 mm thickness while the rest of the machines that are in series production and attached to the same class of the equipment, can cut up to 1-2 mm thickness.

The use of solid-state lasers with pulse pumping for cutting very thick metals (up to 6-10 mm) is more promising if compared to CO_2 lasers or solid-state lasers of continuous pumping and the reasons are as follows.

The wave length of the YAG-Nd3+ laser is 1.06 μ, i.e. 10 times less than that of CO_2 lasers, it allows to get a power density (W/cm^2) by an order of magnitude greater at the same output emission power. Small size and weight of the solid-state pulse source element facilitate the problem of its two-co-ordinate travel in comparison with CO_2 lasers.

Maximum output power of a LTN-103M solid-state continuous laser of series production is limited to 250 W. In case of a beam spot diameter of 0,3 mm as minimum and the power of 250 W, the maximum power density doesn't exceed the 0,35 MW/cm^2. Such density of emission power would perform just surface thermal treatment. Only when oxygen is supplied to a treatment zone, it becomes possible to cut up to 2 mm of sheet materials of low heat conductivity with poor cutting quality and speeds. To cut non-ferrous metals by continuous lasers was proved to be a failure.

The designed lasers of pulse pumping do not have such kind of drawbacks due to their high maximum power density in a pulse mode (300 MW/cm^2) at an average output power of 200 W, 400 J pumping power, 20 Hz frequency, pulse duration of several hundreds of microseconds, 0,14 mm of a beam spot diameter, and an optimized shape of emission pulses. It becomes possible to perform oxygen-free cutting of both ferrous metals of the 6-8 mm thickness and non-ferrous metals, e.g. copper, brass, aluminium, bronze, titanium, etc., of the 4-6 mm thickness, while all the materials being punched through by the first pulse.

In the course of the technology R & D conducted by our specialist, it was discovered that this laser with an adequate beam spot diameter, pulse frequency, and pulse duration will

benefit technical functions of the machine and could perform engraving operation, hole punching of various materials, and metal welding. Besides, it was proved that some qualitative and quantitative process parameters were significantly different at the same average output emission power and pumping energy within the acceptable limits while pulse shapes were varied. At the same time, this helped increasing the efficiency of the whole process.

This shift from a continuous mode of laser emission to a pulse one resulted in a sufficient increase of cutting speed and thickness of ferrous and non-ferrous metals, better quality of cuts (absence of drops of melted metal on the back side of a substrate) at the cost of a smaller average emission power and less mains power consumption in comparison with the actual series lasers.

Our company can design and manufacture custom-made lasers in all options both with technical specifications as it is mentioned and with custom-tailored specifications. It is also available to develop and transfer laser treatment technology for different materials, as well as to fill orders for manufacturing of pieces on our in-situ laser equipment.

We know from our experience with the clients that in the majority of cases laser marking of materials is required along with laser cutting. Since 1987 laser marking techniques have been explored by our company's specialists and the first machines were developed with their help on a public plant of the USSR. The GOI-16 laser (Ulyanovsk, Russia) was used as a basic element. The designed laser machine comprised a precision co-ordinate table with gas lubrication and it assured a marking (engraving) accuracy of the 5-10 μ range and was used for marking-out of measuring tools, scribing of silicon plates, etc. Another task was assigned for the product engineers within a private company in the early 1994, it was to develop a marker of high speeds on the basis of a G-4 scanning head of General Scanning. Increase of laser emission power was required to perform marking operations at the speeds in the 1-3 m/sec range. A technical solution appeared to be in a newly developed multimode resonator, which increased the emission power up to 36 W at the same electrical power consumption. A designed collimator enhanced significantly the output emission quality while the optical system ensured mating with the G-4 scanning

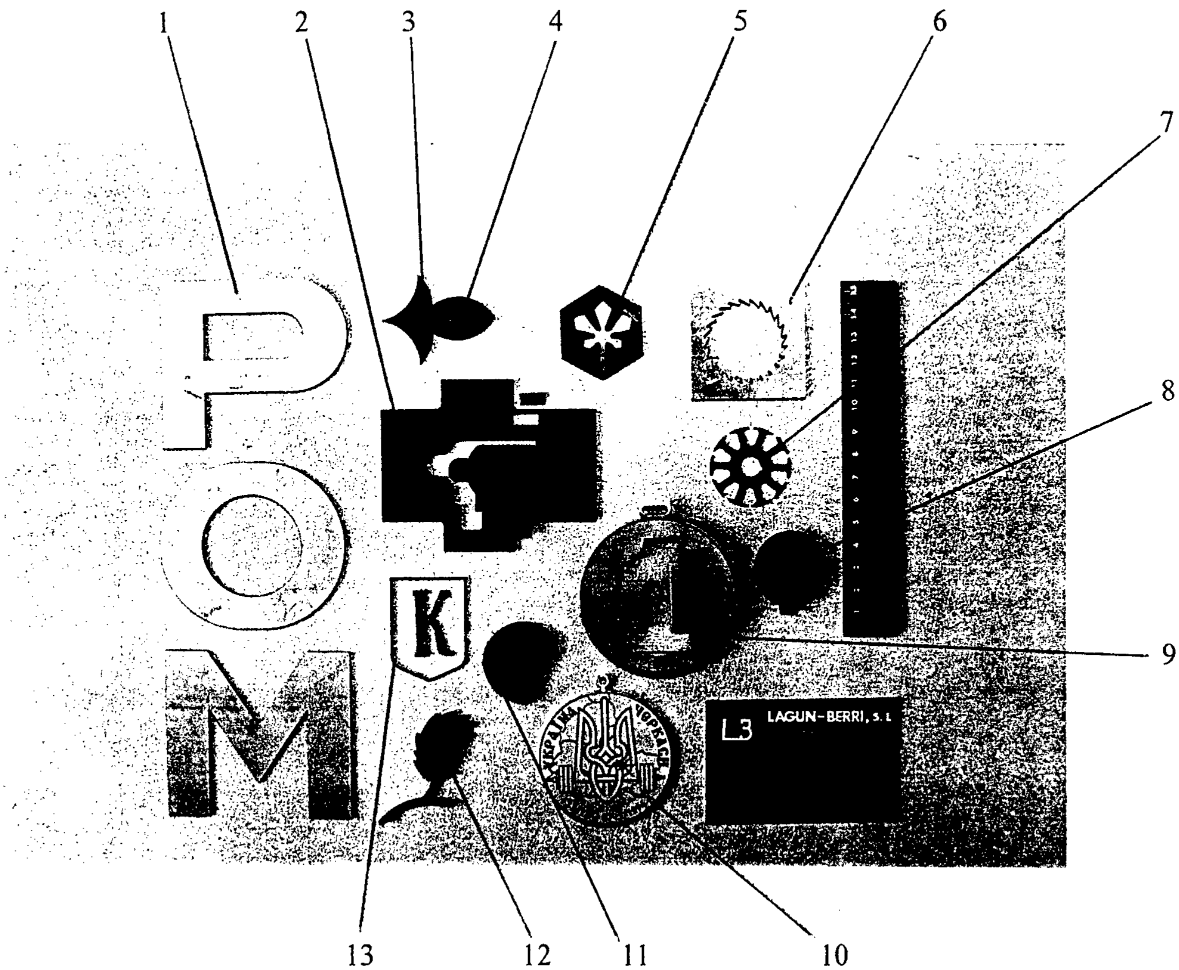
head. Besides, a remote control system for the power source of a pumping lamp and that of acoustic-&-optical gate was made. Based on long experience in the laser marking technology, the specialists developed a method of enhanced "rigid" laser emission by means of increased frequency of the modulation for the acoustic-&-optical gate. All this resulted in the bigger number of materials suitable for marking and a good marking quality. Laser marking data bank has hundreds of technical process descriptions.

At the present moment our company is developing a double laser complex performing processes of precision cutting and precision marking (engraving) in one module. Newly designed one- and two-quantron sources were delivered to the customer while technical documentation having been prepared. Their advantages are as follows: high emission quality; easy manufacturing, assembly and set-up; quickly changeable pumping lamps and quantrons without any resonator alignment. A system for laser beam deviation (scannator) in being developed for the non-precision marking operations (an accuracy of the 0,05-01 mm range on a sport of 100 x 100 mm).

Financing for the developments, trials and tests, adjustment works is being provided by the company while differently proven technical solutions are given to clients. This way of work gives a positive image to the company but it altogether brings conditions of human and financial resources estimations to the working programmes of new technical developments.

Laser Cutting & Marking Samples.

Viktor I. Kikot
"DELFIN-TTT Ltd" Engineering Company
Sumgaitskaya str. 13/1, P.O.Box 1615,
Cherkassy-10, Ukraine 257010
tel./fax 0472-669402, tel.0472-651513

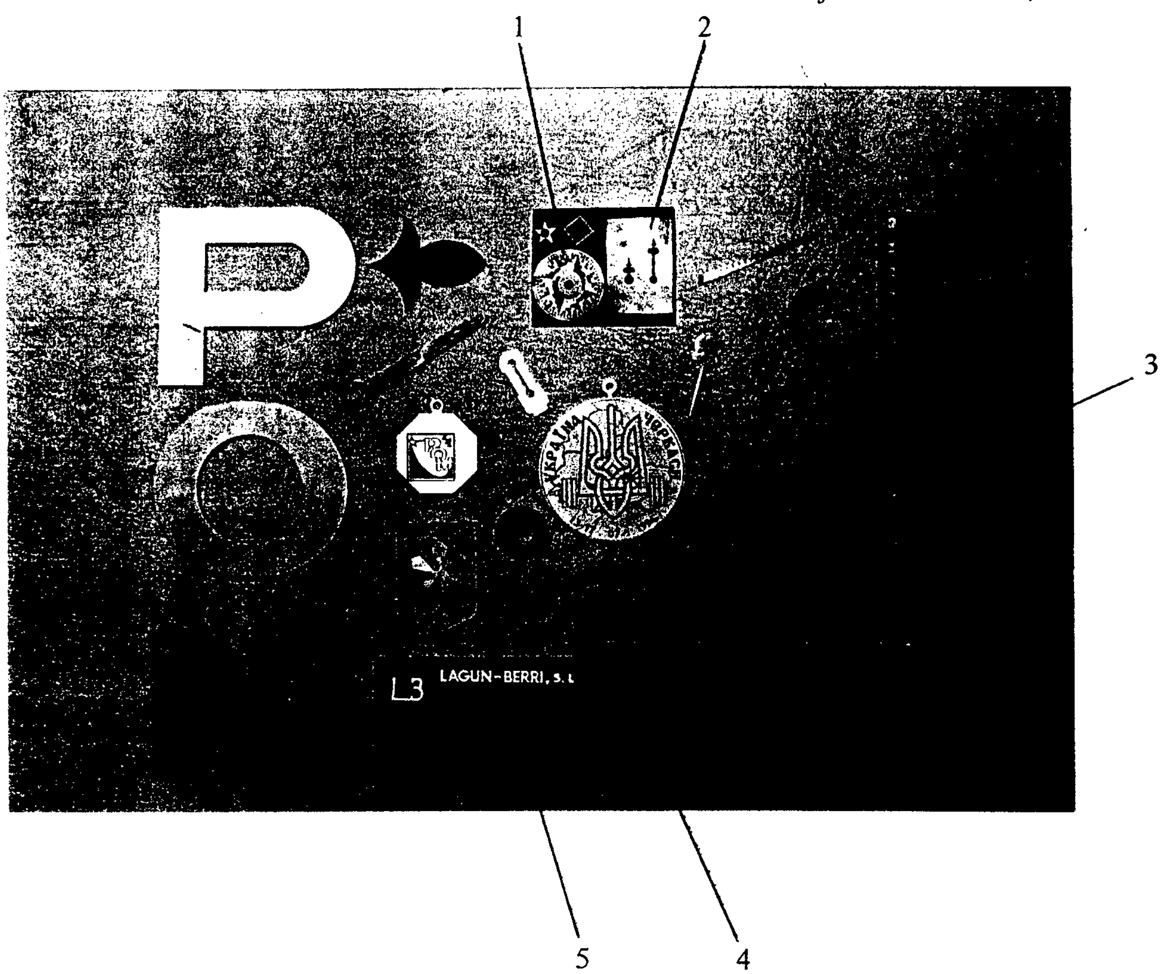


1. Stainless Steel of the 2,00 mm width Thickness. Letters: height in the 2-500 mm range, ~~width~~ Thickness up to 8 mm (copper, brass wide up to 5 mm).
2. Carbon Steel of the 2,2 mm ~~width~~ Thickness. Demo of wasteless cutting-out. 0,1 mm wide cuts.
3. Carbon Steel of the 2,2 mm ~~width~~. Given curvature, any mating of the ideal accuracy.
4. Ceramics of the 2,5 mm width. Any mouldless shape.
5. Carbon Steel of the 3 mm width. AutoCAD is at your service.
6. High-speed Steel of the 3 mm ~~width~~. Inner diameter of the 0,05-0,1 mm range.
7. Transformer Steel of the 0,7 mm width. If you need perfect wound products.
8. Stainless Steel of the 5,3 mm width. This is easy.
9. Stainless Steel of the 4,2 mm width. Be the first.
10. Stainless Steel of the 3 mm width. Cutting + Marking = Quick + Nice
11. Leather of the 3 mm ~~width~~. If you make new models of garments or footwear.
12. 1,8 mm wide Steel, 2 mm wide rubber. This is an ideal stencil for sandblasting treatment of glass.
13. Carbon Steel of the 1,8 mm ~~width~~. There is no such stamp that gives a ratio of the width of material and the width of a piece equal to 5 or greater.

<u>Laser Cutting & Marking Samples.</u>

Viktor I. Kikot

"DELFIN-TTT Ltd" Engineering Company
Sumgaitskaya str. 13/1, P.O.Box 1615,
Cherkassy-10, Ukraine 257010
tel./fax 0472-669402, tel.0472-651513



Thickness

1. Copper of the 0,1 mm ~~width~~. Code wheels for your equipment! This is what you need.
2. Copper of the 0,2 mm ~~width~~. Old clocks and watches are at our service again.
3. Spring Steel of the 2,0 mm ~~width~~. Original fasteners for original equipment.
4. Carbon Steel of the 2,0 mm width. Zn-Cr coatings or any other after laser cutting.
5. Paint and varnish coatings upon Al. A sample of laser marking. Designation strips for your equipment.

1. Surface Treatment, Properties Modification.
Обработка поверхностей. Видоизменение характеристик.

c. Explosion Treatment.
Взрывная обработка

SURFACE MODIFICATION OF IRON-CARBON ALLOYS BY PLASMA-DETONATION TREATMENT

MO INTERM, E.O.Paton Electric Welding Institute, Kiev, Ukraine

Yu.Tyurin

Plasma-detonation method (PDM) is based on the use of the pulse plasma jets provided by transformation of a detonation wave into a plasma pulse. Energy density in such a jet amounts to 10^7 W/cm^2. Consumable electrodes used here allow the vapours of various metals to be introduced into the jet. PDM is applied for heat treatment of surfaces, their alloying, as well as for coating deposition.

Laser treatment is one of the methods currently used to modify surfaces of materials. The drawbacks of laser treatment include large dimensions, low energy utilization factor and high costs of the equipment.

The E.O. Paton Electric Welding Institute is developing a new direction in the area of surface modification, i.e. plasma-detonation treatment (PDT). The high energy density jet is formed as a result of realizing the non-stationary overcompressed processes of detonation combustion of the fuel gas mixtures. Superposition of electromagnetic field onto a detonation wave provides the transformation of the latter into a plasma pulse due to the introduction of an extra energy. The energy density in such a pulse can reach 10^7 W/cm^2, the temperature - 30000 K, the flow rate - 8000 m/s, the pressure at the channel exit - 120 MPa and the pulse duration - 1-5 ms. The device can operate at the frequency of 1-4 Hz.

When such a pulse plasma jet interacts with a workpiece surface, there forms a region of the shock-compressed plasma, which provides a high-rate heating of the workpiece surface. At the same time, in case of evaporation of the central electrode material, heating can be accompanied by the surface layer alloying. The spot 15-18 mm dia. of the modified surface is

formed during one pulse at the 100-150 microns depth of treatment.

Metallographic studies of the transverse sections revealed the presence of a white unetched layer, that coincided mostly with the layer of a higher hardness.

Under the intensive PDT conditions microhardness of the steel surface layer after modification grows up to 10-16 GPa (at some points - up to 19-20 GPa), this being superior to the results observed in laser treatment, fig.1.

Effect of electrode material
on degree and depth of hardening
of 0.8 % C steel in PDT

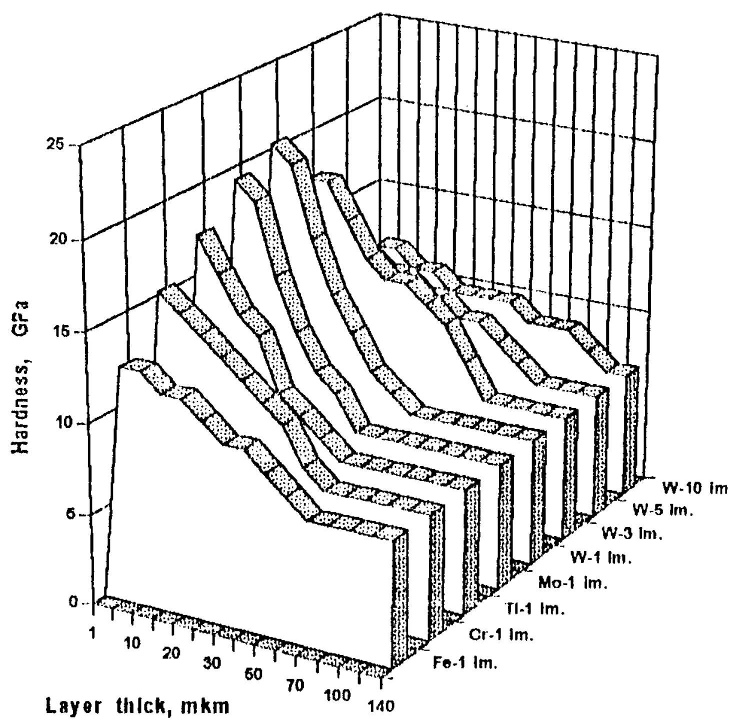


Fig.1.

As follows from the experimental data, after PDT the amount of austenite is higher than in furnace quenching and drastically grows if the modification process is intensified (reduction of the distance and the electrode deepening degree, increase in the number of pulses) and the higher atomic number material electrodes are used for alloying. An increase in the amount of -Fe in these cases can be related to the growth of the heating temperature and to the stabilization of austenite as a result of alloying. The higher austenite content does not

prevent hardening of the surface layer thanks to the high level of heterogeneous elastic distortions of the - phase.

The depth of hardening and the maximum achievable microhardness depend on the PDT conditions, as well as on the central electrode material. The value of the maximum microhardness increases with the growth of the atomic number of the electrode material, being 5 times as high as that of a non-hardened layer in case of the 0.8 % C steel, fig.2-3.

Structure of surface layer of steels *(0,7% C)* after PDT

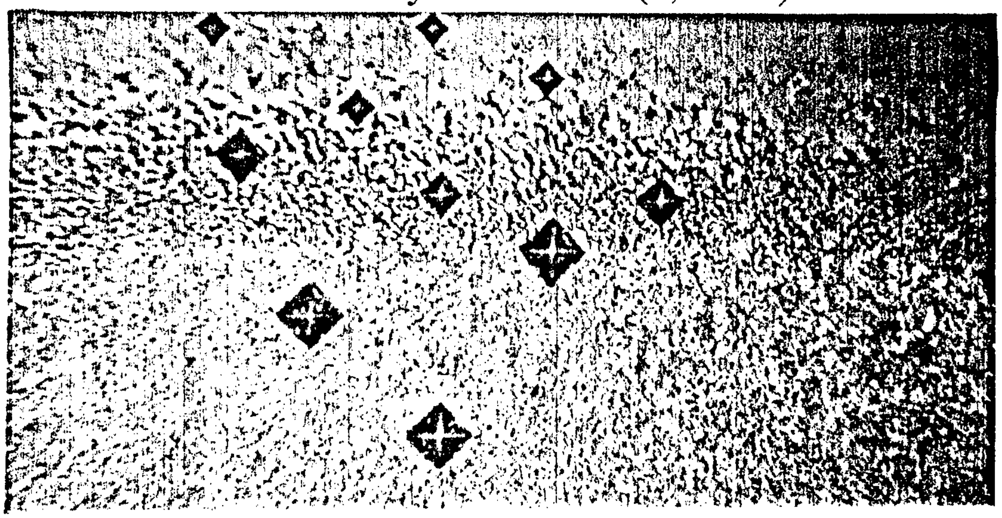


Fig.2.

Structure of surface layer of steels (0,7%C, 1,0%Cr, 1,0 Ni) after PDT

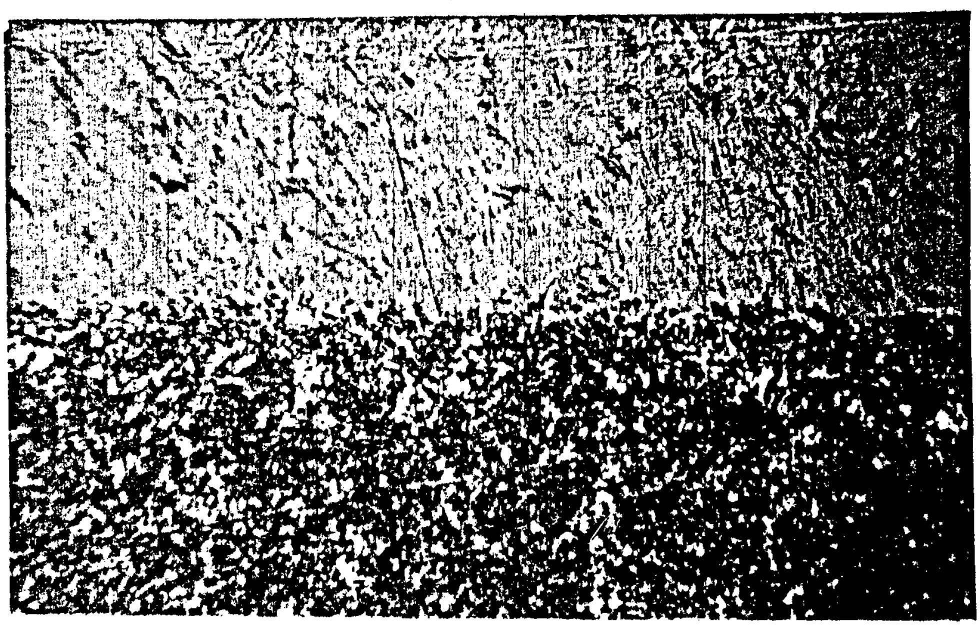


Fig.3.

The technology ensures productivity of up to 300 mm^2/s at the set power of 6 kVA, the flow rate of oxygen being 0.5 m^3/h, fuel gas - 0.1 m^3/h and air - 1,0 m^3/h.

The plasma-detonation technology for modifying the surface of iron-carbon alloys provides the formation of white unetched layers with the increased hardness, which is higher than that of the similar alloys in the quenched state. The effect thus provided is superior to those observed in laser treatment. The practical application of this technology for hardening the blades of knives, saws and other tools results in the 3 to 5 times increase in their service life. The productivity of treatment amounts to m/h, while the specific power consumption is 10 times as low as in the case of the laser technologies.

The technology is realized with the stationary units which are built in automatic production lines. Available are three variants of the technological units:

equipment installed in a specialized room, based on standard manipulators (lathes, millers) and remotedly controlled, fig. 4;

package of equipment comprising noise-proof systems and versatile semiautomatic manipulator, fig.5;

transportable unit for plasma detonation strengthening mounted inside a mobile automatic workshop KM 131 based on cross-country vehicle (the use of other base structure is also possible), fig.6.

PURPOSE. Promotion of the efficient technologies for strengthening machine parts and tools developed in Ukraine and Russia.

AREA OF ACTIVITY.

1. Plasma-detonation strengthening .

1.1. Wood working tools. Metal cutting tools, fig.7.

1.2. Knives for leather, textile, paper and other industries.

1.3. Heavy-duty machine parts and mechanisms.

2. Plasma-detonation spraying of coatings.

2.1. Underwater plasma-detonation technology for spraying of coatings on shaft-type pieces for the repair purposes.

Equipment installed in a specialized room,
based on standard manipulators and remotedly controlled,

Materiais and power resorce consumption
Power,kW.....8
Gas flow,m^3 /h:
-proanc.......0,1
-oxygen......0,5
-air............1,0

Productiviy of treatment
Surfaces, m^3 /h...........0,5
Knife, blades, m/h............10
Saw teeth, pcs/h 1000

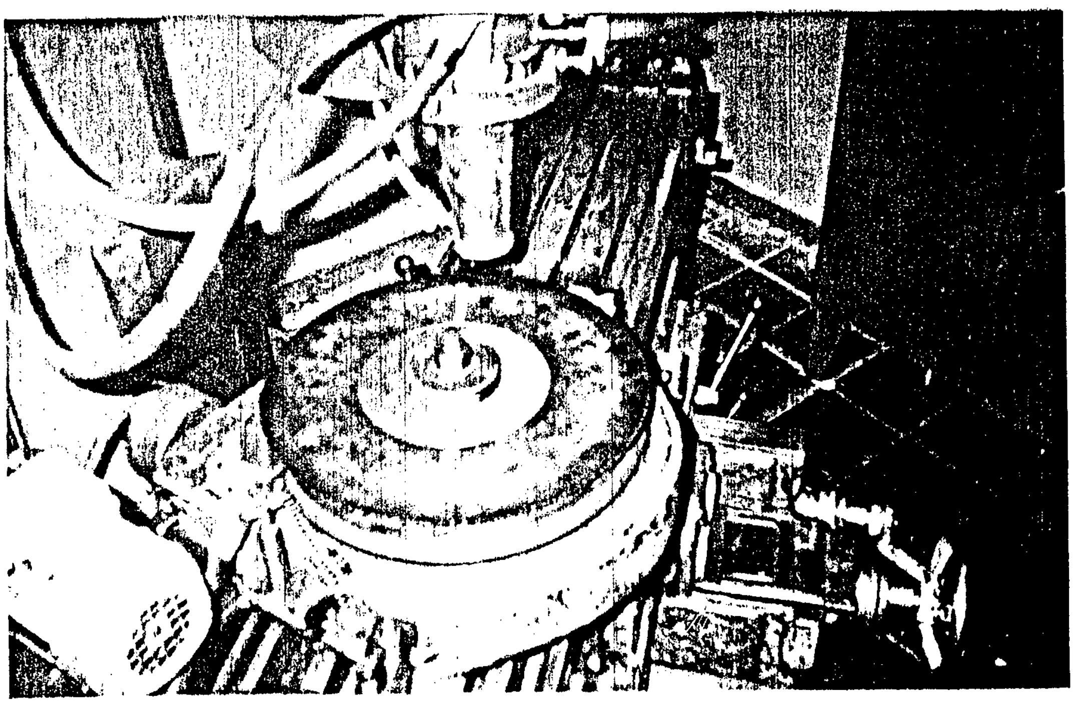


Fig. 4.

Package of equipment
comprising noise-proof systems and versatile
semiautomatic manipulator

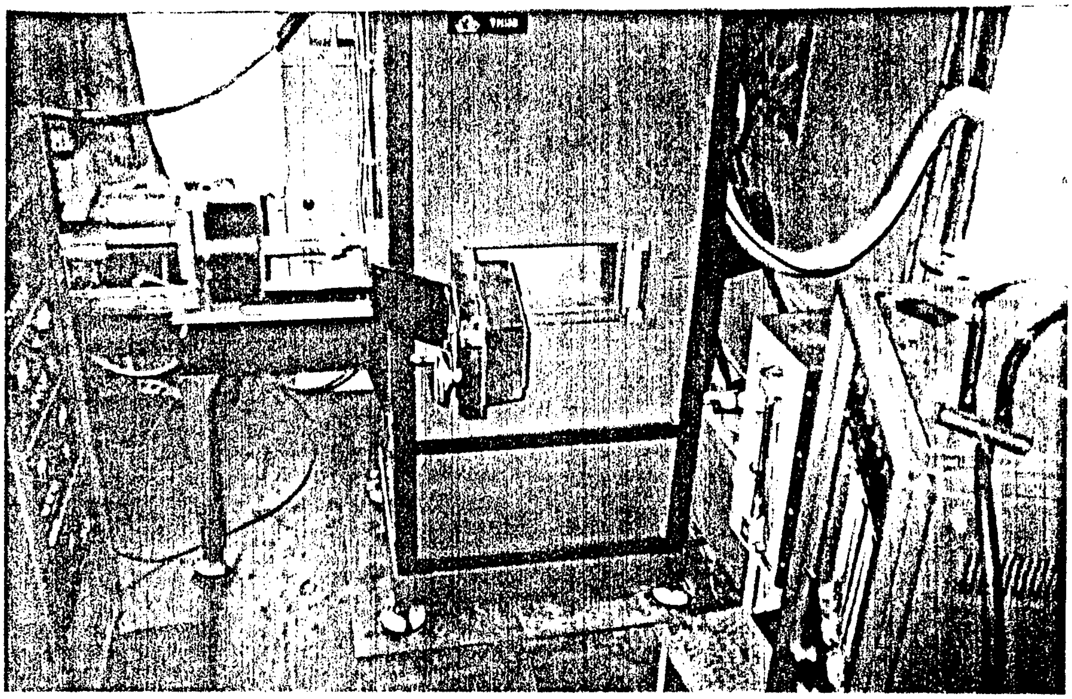


Fig.5.

Transportable unit for plasma detonation strengthening mounted inside a mobile automatic workshop KM131 based on cross-country vehicle.

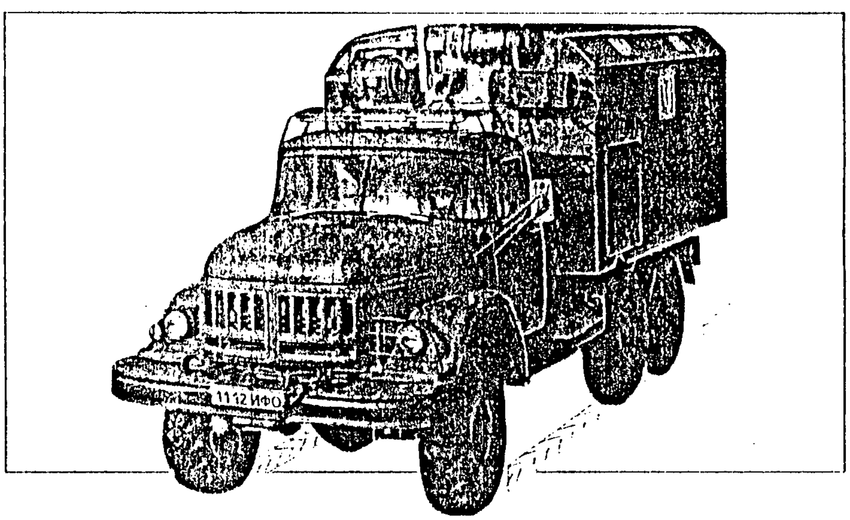
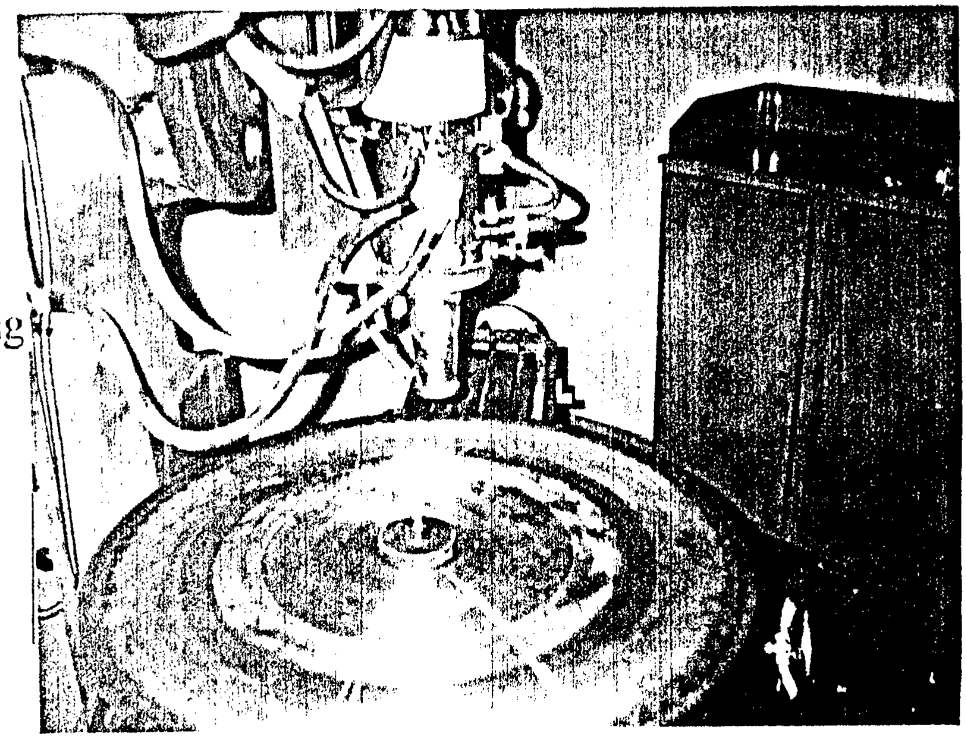


Fig.6.
The use of other base structure is also possible.

PROPOSAL ON STRENGTHENING OF THE WEARING SURFACES OF BLADES, SAWS, ROLLS AND DRAWING DIES IN METALLURGICAL, PRODUCTION

Metal working saw



Metal cutting tools

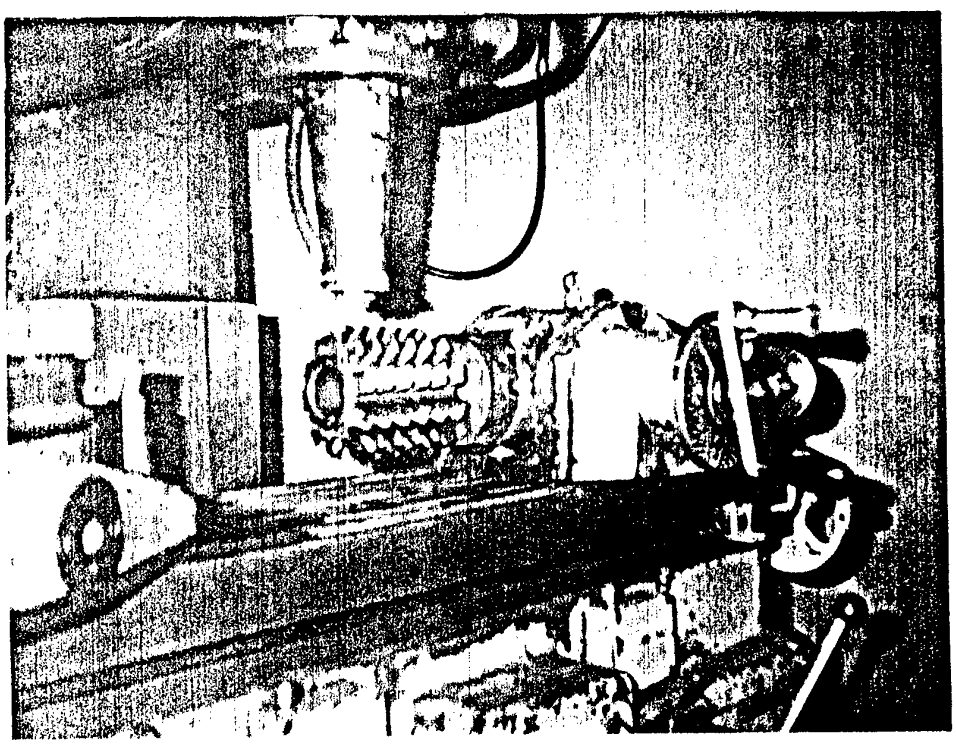


Fig.7.

Pulse High Frequency Thermal Treatment (Technology and Equipment)

BLINOV Yu., KACHANOV B., KOGAN B., FEDOROVA V., SERGEEV A.

" A O K " Ltd.

p/o Pargolovo, 1940446 St.Petersburg, Russia. fax:+7-(812)-3462758; E-mail: root@post.etu.spb.ru

Abstract : High frequency (HF) induction pulse-hardening technology is discussed. Of particular interest are the hardening of non-symmetrical workpieces. A great advantage of the technology is heat removal without external cooling with velocities of quenching up to 10000 $^{o}C*s^{-1}$. The rapid heating of workpieces especially with non-symmetrical geometry can lead in some cases to relatively high level of thermal stresses. The analysis of the stressed-deformation state of the workpiece and an approach for the unified simulation of electromagnetic field, transient temperature distributions, thermal stresses and pulse-power supply are described as well as typical experimental results are shown.

INTRODUCTION

HF induction heating is well-known technological process. It is applied for different technologies. A theoretical description and experimental approval of the process are known when the specific power up to 1-10 $kW*cm^{-2}$ is used. There is induction heating of different configuration of workpiece, galvannealing, forging, extraction, rolling, casting, hardening etc.

HF induction hardening technology (surface and volume) is very wide used in the manufacture of different production. Usually the power range is 10-400 kW and frequency range is 10-440 kHz in the technology.

A good quality of the HF induction hardening technology can be received only taking into consideration the different aspects of the process.

In last time there are some publications[1,2] devoted to the novel approach of the HF induction heating application with the specific power up to 20 $kW*cm^{-2}$. Theoretical understanding of the whole processes into the workpiece to be heat including inductor construction and gap between inductor and workpiece should be reviewed. The level of the specific power demands to limit the energy transferred into the workpiece that leads to the necessity of pulse modes of power supply use. The continuous energy transmission into the workpiece or big duration of pulse lead to part-melting of a surface of workpiece or its melting. Today the follow pulse induction heating technology are known: HF welding of different workpieces, thermal treatment, hardening etc.

HF induction surface pulse-hardening technology is more complicate process both from the point of view of a processes into the workpiece to be hard and an applied equipment for the realisation of the process. The principle advantage of the induction pulse hardening process in differ from the well-known induction heating processes is the use of heat removal without external cooling means, with velocities of quenching up to 10000 degree/sec that deletes a number of an ecological problems and improves the efficiency and reliability of

the equipment and process. Besides the rather high efficiency of the equipment and little power consumption of the process provide essentially higher economic parameters in comparison with the similar process in which the laser beam is used. Moreover in the laser hardening the thickness of hardened layer can not be greater then 0.5 mm because the thermal sources are located only on the surface of a workpiece. The increase of the hardened depth can be reach only with the part-melting of the workpiece surface. In the HF induction pulse hardening technology specific power equals to 1-10 $kW*cm^{-2}$. Heating times usually is below then 400 msec. Power range is 60-100 kW, frequency range 66-440 kHz. In the process there are not restrictions of heat speed of a workpiece surface because the thermal sources in the HF induction pulse hardening are placed directly into a workpiece on a current penetration depth. The thickness of hardened layer in the technology is defined by frequency of current and specific power and can reach 1.5 mm. However, the rapid heating of a workpiece especially with non-symmetrical geometry leads in some cases to local overheating and relatively high level of thermal stresses. The analysis of the stressed-deformation state of the workpiece is therefore necessary for the application of the pulse-hardening process, since these stresses, added to preexisting external stresses, can give rise to the appearance of a microcracks. However despite on the above listed advantages the realisation of a good quality of the technological process requires the decision of a lot of problems for its wide introduction in an industry. There are:

- development of construction principles of the industrial equipment for pulse high-frequency hardening, ensuring the low cost price of the technological process;
- development of typical design of inductors, ensuring operation at specific power 10 $kW*cm^{-2}$;
- theoretical and experimental study of a physical processes, proceeding at pulse treatment of a workpieces at high specific power.

EQUIPMENT NECESSARY FOR THE TECHNOLOGY

Realisation of the HF induction pulse-hardening technology demands to overview: the operation modes of the power supply, construction of inductors, matching conditions of power supply and inductor.

POWER SUPPLY. Today for the realisation of the technology two types of power supplies can be used - vacuum-tube or transistor[3]. In mentioned above frequency and power range taking into consideration pulse mode of operation it's more easy to realise the technology with the use of vacuum-tube generator.

These modes can be received simply enough and do not require significant changes in the scheme of generator[4]. The influence on the grid circuit of generator is the base of pulse-periodic modes that permits to interrupt self-exciting conditions for definite time. Theoretical and experimental investigations for 440 kHz installations in power range 10-600 kW gave opportunity to define the maximum value of low frequency modulation (10-15 kHz) which depends on parameters of oscillator circuit. Minimum value of low frequency pulse duration also depends on mentioned above value and is in range 100-200 ŕs. Times on-off of generator are in the range 50-100 ŕs at frequency 0.44 MHz.

The use of transistor generators in mentioned above frequency and power ranges demand to realise a pulse-periodic mode. The first way is the use of frequency change control that can give a good results for high

Q-factor of a load. The problem of overvoltage on the generator elements must be solved. The last problem does not permit to decrease the times on-off of generator and at hardening of a number of workpieces does not give the wishes results. Special units, control laws or something else must be suggested for the solving of the delivered problem.

The vacuum-tube generators were used for the experiments.

CONSTRUCTION OF INDUCTOR. The increased reliability of operation at large specific powers is one of the main requirements for the inductor design. It can be achieved by the use of the inductor with increased surface of a heat removal. The decision of a delivered problem is considerably complicated as the area of an active surface is as a rule essentially limited and not exceed 2-4 cm^2 and as rule inductor has one turn. It is caused by rather small power of supply sources and necessity in the majority of cases to execute local heat treatment of workpieces. By this reason at the development of inductors it's necessary to take into account high thermal conductivity of cooper, to increase the sizes of heat removal parts of inductor leaving an active surface of inductor without changes which must to satisfy to the requirements of technological process. Proceeding from it a current parts of inductor, the surface of which is active, should be made as bulky details, made from cooper and having a qualitative contact, which is provided at the use of profiles cooling tubes and soldering of high-temperature alloys. In this case the size of tubes should be increased not less than at 20%, providing of a condition for realization of the soldering and reducing hydraulic resistance of a cooling system. Availability of magnetic concentrators is the important factor, influencing to a quality of thermal treatment and to an opportunity of concentration of energy in small volume. Magnetic concentrators enable to move the current on an active surface of inductors, as well as enable to increase their inductance, that rather important for choice of matching conditions of the power supply and a load, as it was already marked above. As a rule at pulse high-frequency heat treatment power supplies with frequency of a current not below 66 kHz are applied, that results to necessity of application as yoke of ferrite. In case of pulse-periodic mode of operations use a great attention should be given to a temperature field of ferrite, which operates in strong fields, having rather bad cooling, that is connected with their low thermal conductivity at the absence of special systems of a heat removal. A unique way, enabling to ensure reliable conditions of operation, is the increase of working volume of a yoke. The process of a pulse high-frequency hardening is the most effective in case of operation with minimum gaps between an active surface of inductor and workpiece as thus intensity of a magnetic field is maximum, that in turn permits to ensure the heaviest depth of distribution of thermal sources, increasing a speed of heating, and consequently mechanical properties and depth of hardened layer. The specified conditions of operation result to necessity of special preparation of active surfaces of inductors and magnetic concentrators, executed from ferrite, providing their high accuracy of manufacturing. Besides the working gap in the majority of cases makes 0,1 mm there is necessity of putting of special dielectric covers having high mechanical properties. To such covers it is possible to relate a covers on the basis of mineral-ceramics or oxide of aluminum.

MATCHING CONDITIONS. The choice of matching conditions is the key problem under realisation of the HF hardening technology. Low voltage inductors with a low value of equivalent inductance applied at the technology demand to make some changes at the HF generator. The application of the known vacuum-tube as well as transistor generator leads to the necessity of the use, first of all, of matching HF transformer to decrease

the value of voltage that has the positive fact because the value of equivalent inductances on the primary winding of the transformer is increased. The Q-factor of the resonance circuit included compensation condensers and inductor is more bigger for the vacuum-tube generator then for transistor generator.

In case of vacuum-tube generator it leads to simplicity of power matching conditions of oscillate circuit and vacuum-tube and to operation of generator in the permitted by standard of frequency range. (For frequency 440 kHz the tolerance of frequency according to the standard equals to ±2.5%) Moreover there are additional adjustable elements in oscillate circuit, for example controller of feedback, controller of power, that make more simple the power matching at the change of inductors and workpiece.

Transistor generator with low Q-factor demands the exact way of generator parameters choice, but in any case the change of a frequency during the heating will be bigger then for vacuum-tube generator. Besides the bigger change of frequency during the technological cycle for the transistor generator leads to the change of the power matching conditions that compel to review of the power of the generator. The negative aspects of the last problem is known i.e. the possible overheat of some parts of the non-symmetrical workpieces.

DESCRIPTION OF SIMULATION PROCEDURE

The simulation algorithm of hardening process can be divided on four basic parts:

1. Solving of electromagnetic problem with the aim of calculation of thermal sources distribution into the workpiece.

2. Calculation of electromagnetic processes in power supply.

3. Calculation of non stationary thermal field including the definition of physical-mechanical properties of metal on the different tages of heating and quenching.

4. Definition of stresses and deformations on the each calculation stage.

ELECTROMAGNETIC AND THERMAL PROBLEMS. As known the induction heating process can be decsribed by Maxwell's and Fourier's equations. The analitical and numerical methods of the equations solving are developed. The electromagnetic characteristics of workpieces depend on temperature and electromagnetic field intensity. In the work for the electromagnetic and thermal problems solving the next assumptions were made.

The particularaty of the technoly is the use of minimum gaps with a big specific power that leads to a high level of electromagnetic field intensity. The last fact makes right assumption about the necessaty to describe ferromagnetic workpiece in the range under inductor with relative magnetic permeability equals to 1 (r=1). Besides there is yoke arrounded inductor that gives the form of current distribution in the workpiece as almost rectangle. The sizes of current conductivity range is defined by both the narrow of induced conductor and the depth of current penetration in metal under the pre-given frequency, specific resistivity and relative magnetic permeability. Thus the thermal sources distribution in the workpiece can be define without the elctomagnetic problem solving only for the case of the HF induction pulse-hardening technology.

2D-model based on finite elements method is applied for the definition of temperature distribution in the workpiece. The calculations were carryied out for the heating and cooling of the workpiece. There is not external heat removal and heat removal from the surface of workpiece is negligible. The temperature distribution in the workpiece near the inductor is calculated only because heating time is little and heating is carried out for limited range. The choice of number and size of elements is defined by geometry of the workpiece and depth of current penetration in metal. In further the same elements are used for calculation of stress-deformation state.

HF GENERATOR SIMULATION PROBLEM. The final aim of HF generator modeling is steady-state process, which gives load voltage and frequency. For this purpose different approaches can be applied: a) Cauchy Problem solving; b) Boundary Value Problem solving[5]; c) simplified approach for the receiving of the load voltage and frequency values[6]. In the work the Cauchy Problem solving was used. In all these three approaches the vacuum-tube or transistor model should be used. Vacuum-tube is a non-linear element for which anode $i_a=f_1(u_a,u_g)$ and grid $i_g=f_2(u_a,u_g)$ currents are known. Using values u_a and u_g the values of the i_a and i_g currents are defined. It is very simply to have the model of the tube as two dependent current sources the values of which re defined in accordance with the handbook characteristics using the interpolate polinoms. The similar model of MOSFET transistor should be used for simulation of solid-state generator. The characteristics of MOSFET transistor also is shown in handbook and taking into attention valve mode of transistor operation its characteristic can be defined as dependent current source. Schematic model of transistor, which is used, for example in PSPICE, is more complicate, demands the definition of a number of internal transistor parameters and leads to the increase of calculation time. For simulation of the hardening as well as other HF technologies the pointed out transistor model gives the good accuracy. In the Cauchy Problem case transient and steady-state processes of generator can be obtained. Generator is described by the system of ordinary differential equations (ODE) in the state variables form. State variables include voltages on capacitances and currents through inductances. Solving the Cauchy problem with initial values $x(0)=X$ at $t > t_0$ we reach steady-state process after definite time. ODE system is formed automatically with using well-known algorithms[7]. It is necessary to define only the numbers of nodes, the types and the number of elements and the values of these elements. ODE system is solved on every discrete step by chosen integration method. Usually characteristics of vacuum-tube and transistor are smooth non-linearity that give a good accuracy under calculation. These basic principles were used in the program of HF generator simulation[4].

THERMAL STRESSES PROBLEM. The possible local overheat and comparatively high level of thermal stresses in the technology lead to the necessity of theoretical analysis of stressed-deformation state of hardened workpiece[8]. Non equal plastic deformation and a non equal temperature in different points of workpiece are the main cause of internal stresses. Under the any thermal treatment of metal the internal stresses can be appeared which could be add to external stresses and then the result stresses can be strengthen or slacken. The tensions are most risk because they could be add to external tensions that leads to the appearance of microcracks. The connection between elastic deformation and heat transfer is negligible under heating and it is not taken into account. The last one usually is described by six components which are the forces per square and are applied to relatively perpendicular surfaces passing through investigated point. Stresses compressing element are negative

and stretching stresses are positive. Three conditions of equilibrium might be written if gradients of stresses and forces which are applied to little volume are in equilibrium

$$\frac{\Sigma\partial\,\sigma_x}{\partial\,x} + \frac{\Sigma\partial\,\tau_{xy}}{\partial\,y} + \frac{\Sigma\partial\,\tau_{xz}}{\partial\,z} + x = 0$$

$$\frac{\Sigma\partial\,\sigma_y}{\partial\,y} + \frac{\Sigma\partial\,\tau_{xy}}{\partial\,x} + \frac{\Sigma\partial\,\tau_{yz}}{\partial\,z} + y = 0 \qquad (1)$$

$$\frac{\Sigma\partial\,\sigma_z}{\partial\,z} + \frac{\Sigma\partial\,\tau_{xy}}{\partial\,x} + \frac{\Sigma\partial\,\tau_{yz}}{\partial\,y} + z = 0$$

These equations valid into all volume of workpiece. Additionally boundary conditions are written. Definition of stressed state in workpiece is possible under the solving of differential equation system of equilibrium. However it's necessary to describe the deformation of elastic body. Under deformation components of movement (v, u, w) in the point are described follow equations

$$\varepsilon_x = \frac{\partial u}{\partial x}, \qquad \varepsilon_y = \frac{\partial v}{\partial y}, \qquad \varepsilon_z = \frac{\partial w}{\partial z}.$$

$$\gamma_{xy}=\varepsilon_x+\varepsilon_y, \qquad \gamma_{xz}=\varepsilon_x+\varepsilon_z, \qquad \gamma_{yz}=\varepsilon_x y \varepsilon_z.$$

Previous parameters are components of deformation and they are the movement of points divided to initial distance between their. Initial equations for calculation of stresses with continuous functions u, v, w which define deformation could be received with differential equations (1)

$$\frac{\partial^2\,\varepsilon_x}{\partial\,y^2} + \frac{\partial^2\,\varepsilon_y}{\partial\,x^2} = \frac{\partial^2\,\gamma_{xy}}{\partial\,x\;\partial\,y}$$

$$\frac{\partial^2\,\varepsilon_y}{\partial\,z^2} + \frac{\partial^2\,\varepsilon_z}{\partial\,y^2} = \frac{\partial^2\,\gamma_{yz}}{\partial\,y\;\partial\,z}$$

$$\frac{\partial^2\,\varepsilon_z}{\partial\,x^2} + \frac{\partial^2\,\varepsilon_x}{\partial\,z^2} = \frac{\partial^2\,\gamma_{xz}}{\partial\,x\;\partial\,z}$$

The last ones and boundary conditions give system which is valid for calculation of whole distribution of stresses into body.

MUTUAL SIMULATION PROBLEM. As seen a simulation of this unified process is very complicate, because the different types of equations describe the coupling process. Simulation of induction heating process demands

the use of partial differential equations. Simulation of mechanical processes demands also the use of partial differential equations and simulation of power supply demands the use of ordinary differential equations.

The unification of these three tasks is the main problem of simulation because before the software for the separate simulation of these processes had been developed[4,5,9]. First of all the procedure of iterative algorithm has been created for coupling simulation of HF hardening of workpieces and generator[10].

The main stages of this algorithm are the next:

a) the definition of inductor current and frequency;

b) the calculation of electromagnetic HF process in workpiece;

c) the receiving of new inductor current value;

d) if the difference between previous and new values of inductor current is greater then pregiven tolerance go to b);

e) calculation of inductive (l) and resistive (r) components of inductor with workpiece;

f) calculation of self-exciting generator with l and r parameters;

g) the definition of inductor current;

h) if the difference between last inductor current value and previous one is greater then pregiven tolerance go to b);

i) calculation of thermal sources distribution in workpiece;

j) calculation of thermo-mechanical stresses in workpiece.

The developed algorithm and software give opportunity to calculate:

1) the distribution of specific power along workpiece to be hard with taking into consideration the possible change of geometrical sizes of hardened range during the process of workpiece part-melting if its necessary;

2) mechanical internal strains into the hardening workpiece which are explained both the heating and the phase evolution during the heat;

3) the energy characteristics of generator during the hardening process.

The simulation of the process gives post-heat internal strains which can be add to work workpiece strains and hence to destroy the workpiece.

The optimum heating process can be simulated for the choice of the minimum strains into the workpiece after the heat.

DESCRIPTION OF SIMULATION RESULTS

On fig. 2 temperature fields, received at heating of boundary of a workpiece, submitted on a fig. 1 are indicated. The temperature field is changed essentially and depends on a level of specific power and heating time . The increase of specific power up to $7{,}5 \cdot 10^4$ W$\cdot$cm^{-2} and reduction of pulse duration up to 150 ms (fig.4) provides occurrence on a surface of a workpiece relative high temperatures, though the area of temperatures is appropriate to a range 600-800 ^{o}C. The field of thermal stresses is differed at comparison of first two variants (fig.4), though the general character has not undergone significant changes despite on

differences in absolute values. Thus it's possible to make the conclusion about inexpediency of realization of technological process at a pulse duration less than 100 ms because in this case it is possible to melt a surface of metal. For maintenance of given depth of a hardeneed layer at absence of melting on a surface it is necessary to decrease the specific power. The results of calculations are indicated on fig.3-5. Availability of compressing and decompressing stresses, placed in various areas of a workpiece, permits to make the conclusion about an opportunity of destruction of workpiece on a border of section, that especially essential at operation on high frequencies with large specific power.

DESCRIPTION OF EXPERIMENTAL RESULTS

In the Table 1 results of experiments are indicated for ferromagnetic steel U8 which were received on industrial vacuum-tube generators with self-exciting, operating in pulse and pulse-periodic modes. Mechanical properties of metal are not worse then 64 HRC for indicated samples in a zone of a hardened layer. The size of a hardened layer has been defined as result of metalgrafic researches on change of a structure of metal.

Table 1

Values of hardened layer depth at pulse hardening of a plate boundary by thickness of 45 mm for steel U8 at specific power not less than 4,7*1000 $W*cm^{-2}$.

sample number	time of processing, ms	Depth of hardened layer in mm	
		at frequency 66 kHz	at frequency 440 kHz
1	100	1.087	0.535
2	150	1.315	0.730
3	200	1.380	0.865
4	250	1.425	0.975
5	300	1.830	1.065
6	400	1.680	----

The increase of pulse duration at constant specific power results to the increase of hardened layer depth up to finite values and then on a surface melting area is formed. The value of a hardened layer depth is decreased, that is explained by an increase of a zone of thermal influence and results to decrease of cooling speed. Reception of a thermal treatment zone by operation of power supply on frequency 440 kHz at large pulse duration results to formation of a metal splashing due to electrodynamic forces, influencing on melting metal.

CONCLUSIONS

Unified approach to simulation of electromagnetic field, thermal distribution, thermal stresses, power supply is suggested. The explanation of high microhardness was done under heating with high specific power. Experimental results confirm the validity of model. The real technological application of pulse induction heating were explained.

REFERENCES

1. M.Zukov, V.Schukin, V.Neronov etc.: 'High-Frequency Pulse Hardening of Steel', *Physics and chemistry of materials treatment*, 1994(6).98-108. (In Russian).

2. A.Vasiliev, B.Kogan, B.Kachanov: 'Pulse Induction Heating', *Electrotech'92, Proceeding of XII-th Congress UIE, Montreal (Canada), 14-18 June*, 1992. 36-39.

3. E.J.Dede, J.Jordan, J.V.Gonzales etc.: 'Conception and Design of a Parallel Resonant Converter for Induction Heating', *Proceedings of 6-th Annual Conf. APEC'91, March 10-15, Dallas (USA)*, 1991, 38-44.

4. Yu.Blinov., B.Kogan, A.Vasiliev etc.: 'Methods for Analysis and Control of Vacuum-Tube Oscillators for Electrothermy Applications', *Soviet electrical engineering*, 1987, **58**(8). 33-36.

5. Yu.Blinov, A.Vasiliev, S.Gurevich etc.: 'Methods of Modeling of Vacuum-Tube Oscillators in Range Frequency 1ч40(80) MHz' *Int. Congress MW & HF - Nice (France)*, 1991. 177-180.

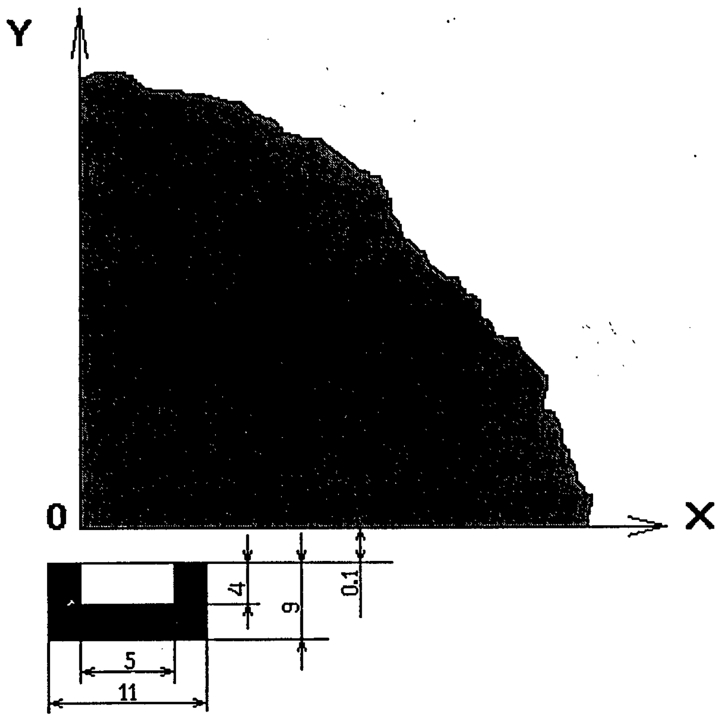
6. Yu. Blinov, S.Lupi, F.Dughiero: 'Mutual Influence Between Load and Frequency Converter in the Induction Heating of Steel', *Proceedings of Int.Conf. Industrial Electronics, Control and Instrumentation (IECON'94), 5-9 September, Bologna (Italy)*, 1994. 679-683.

7. L.Chua, Pen-Min-Lin: 'Computer-Aided Analysis of Electronic Circuits. Algorithms and Computational Techniques', Engl. Cliffs., 1975.

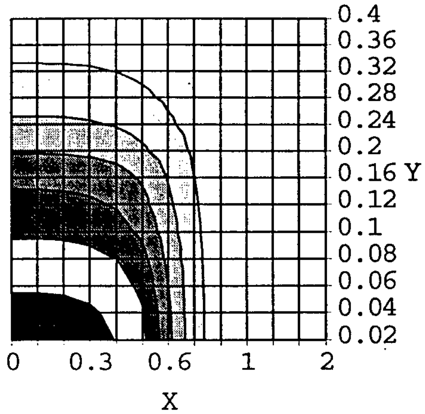
8. Yu.Blinov, B.Kachanov, V.Fedorova etc.: 'Influence of High Frequency Power Supplies under Analysis of Thermal Deformation in the Electrotechnological Processes with High Level of Specific Power'. *Proceedings of Int. Symposium Scientific problems of HF electrotechnology, 28-30 June, St.Petersburg (Russia)*, 1994. 135-140.

9. F.Dughiero, S.Lupi: 'The Control of Temperature Transients in the Induction Heating of Steel', *UIE-Seminar, Heat Transfer in Electroheat, Lodz (Poland), 22-25 Oct.* 1991. 61-67.

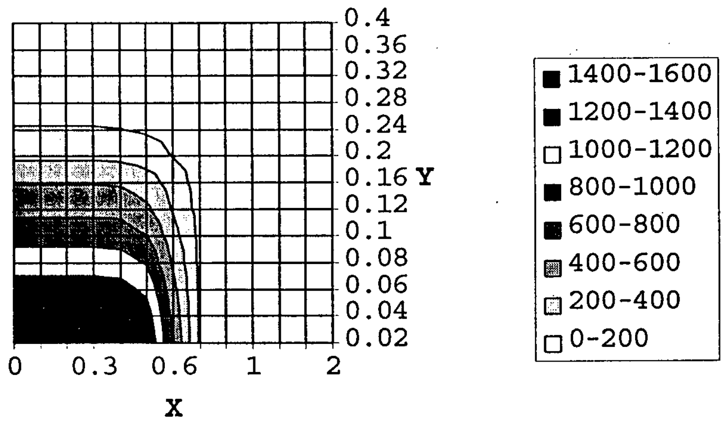
10. Yu.Blinov, F.Dughiero, S.Lupi: 'Influence on the Frequency Converter Characteristics of the Inductor-Load Impedance Variations in the Induction Heating of Steel', *Int.Conf. EDR&PE'92, September 14-16 - Kosice (CSFR)*, 1992. 233-235.


Y
0
X
4
9
0.1
5
11

a).



b).



c).

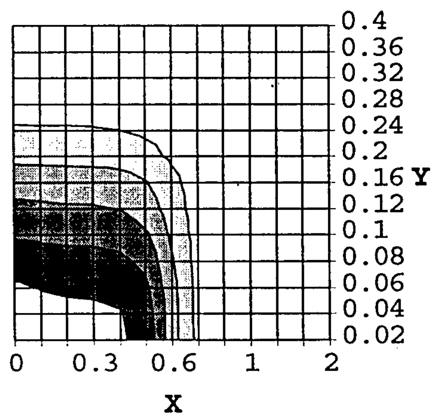
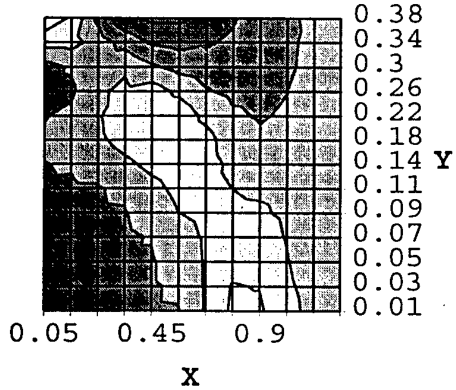
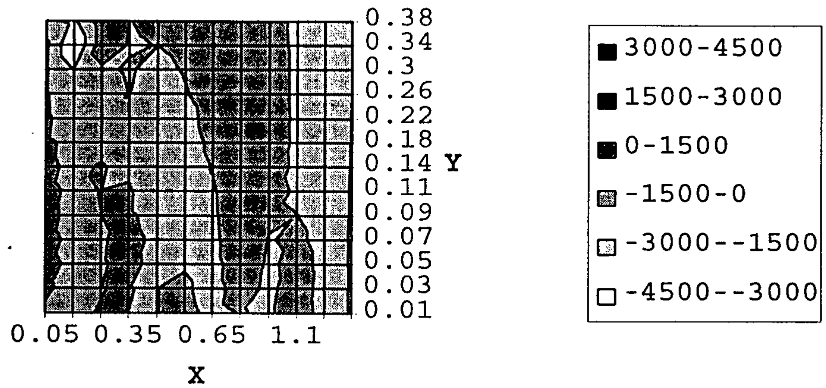


Fig. 2. Temperature fields (scale in °C) in the pulse harding:
a). mode I; b). mode II; c). mode III.

a).



b).



c)

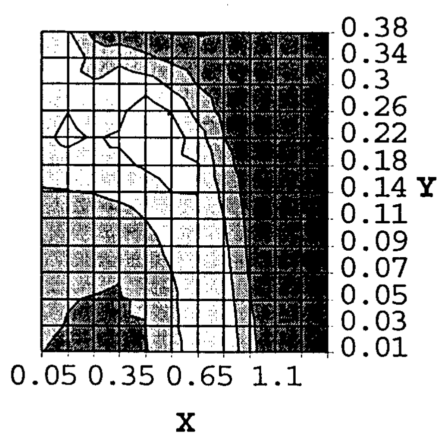
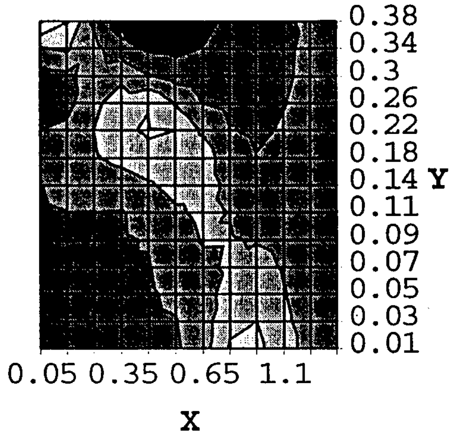
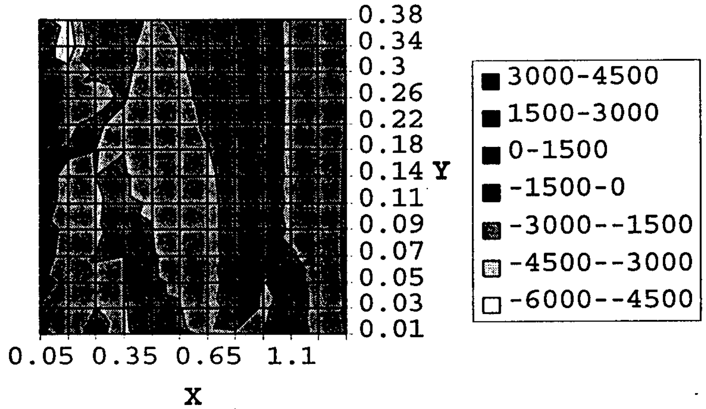


Fig. 3. Thermal stresses (kg/cm^2). Mode I.
a). σ_x; b). σ_y; c).σ_z.

a).



b).



c).

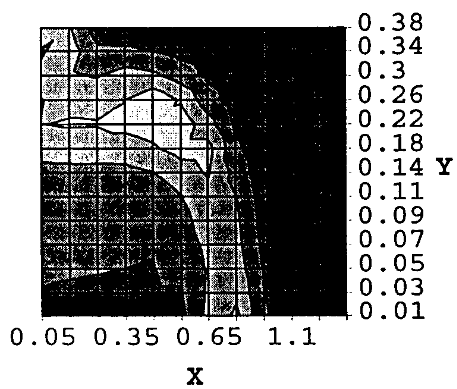
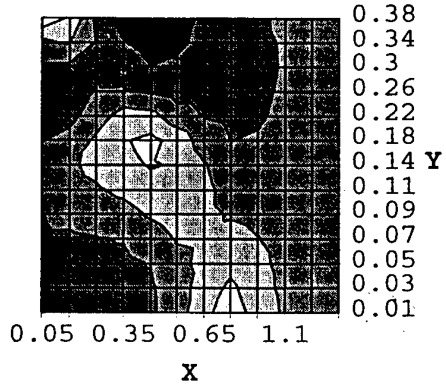
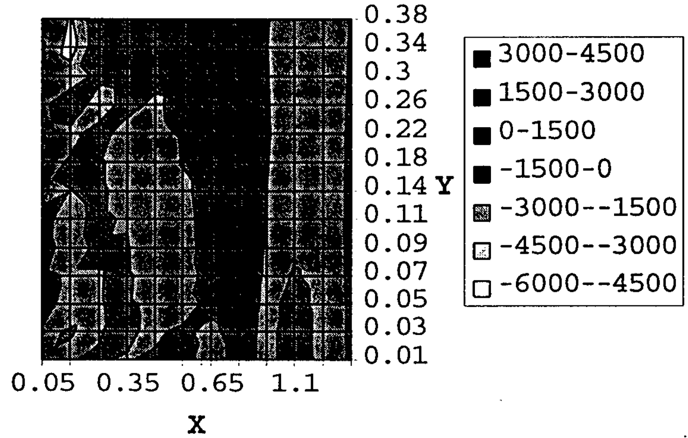


Fig. 4. Thermal stresses (kg/cm^2). Mode II.
a). σ_x; b). σ_y; c). σ_z.

a).



b).



c).

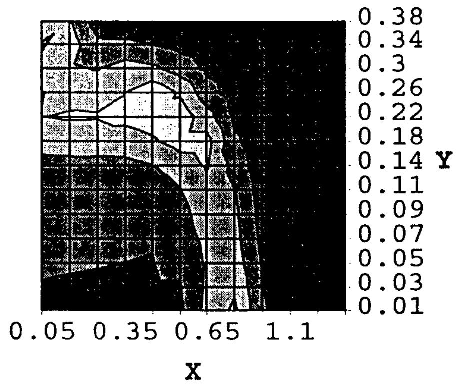


Fig. 5. Thermal stresses (kg/cm^2). Mode III.
a). σ_x; b). σ_y; c). σ_z.

2. Laser Technologies.
Лазерные технологии

a. High-Power Lasers.
Высокомощные лазеры

2. Laser Technologies.
Лазерные технологии

b. Novel Technologies and Applications.
Новейшие технологии и их применение

TCHEREDNICHENKO O.

ACOUSTOOPTICAL FILTER FOR TUNABLE LASERS

1.General information on acoustooptical filters

Acoustooptical tunable filter (AOTF) is a synthetic birefringent monocrystal in which an ultrasonic wave forms a controlled diffraction grating (Fig.1). The wavelength of AOTF transmission depends on a period of this grating given by the frequency of voltage influenced upon AOTF through a piezoelectric transducer. Electronic control of the ultrasonic grating allows to produce a fast tuning of AOTF transmission wavelength in arbitrary way.

AOTF transmission wavelength and bandwidth are:

$$\lambda(f) = \frac{v\,(n_o - n_e)}{f}; \qquad \delta\lambda = \frac{\lambda^2}{(n_o - n_e)L},$$

where v and f are the sound wave velocity and frequency, n_o and n_e are refractive indices, L is crystal length.

2.Tunable laser with acoustooptical control

The following configuration may be offered as a typical one for a tunable Ti:Sapphire Laser (Fig.2).

Owing to multipassage spectrum narrowing the laser emission bandwidth may be less then the AOTF transmission bandwidth by a factor of 5...7. The use of an amplifier allows to increase the laser efficiency as well as the output power of single mode emission. The AOTF may be also used in a tunable Dye Laser.

3. AOTF control unit

A HF voltage applied to the AOTF controls the wavelength tuning. Its frequency varies within 20...40 MHz at power about 5 W. The AOTF control unit (CU) is a separate unit with external computer control (IBM PC-AT/386 or above). The CU functions include also the AOTF temperature control (to stabilize the wavelength) and nonlinear crystal rotation control (for second and third harmonics generation).

4.Specifications

The following parameters a possible for Ti:Sapphire Tunable Laser :

Fundamental tuning range, nm..700...1100*
second harmonic..350...550
third harmonic..235...360
Bandwidth, nm..0.1...0.3
Wavelength setting accuracy, nm..0.02
Scanning step, nm..<0.01
Wavelength switching time, ms:
at tuning within -1...+1 nm..1
at tuning all over the range..<3
Pumping conversion efficiency, %..up to 30
Second harmonic efficiency, %..up to 30
Third harmonic efficiency, %..up to 35
Efficiency of diffraction in AOTF, %...>90
Power density of AOTF crystal optical breakdown, MW/cm^2.................>200
AOTF overall dimensions, mm..15x35x100

* for Dye Laser: 540...720 nm;
360...430 nm (sum-frequency mixing);
270...360 nm(second harmonic).

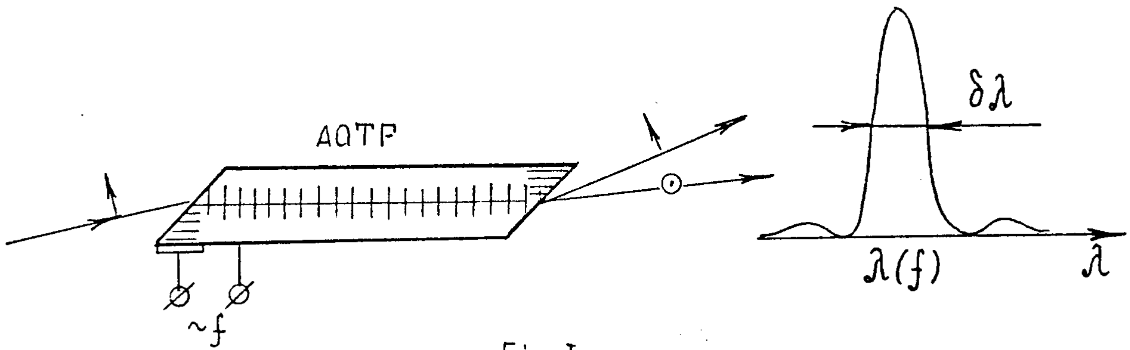


Fig.I

Fig.1. Configuration of an acoustooptical filter, its transmission bandwidth as a function of wavelength.

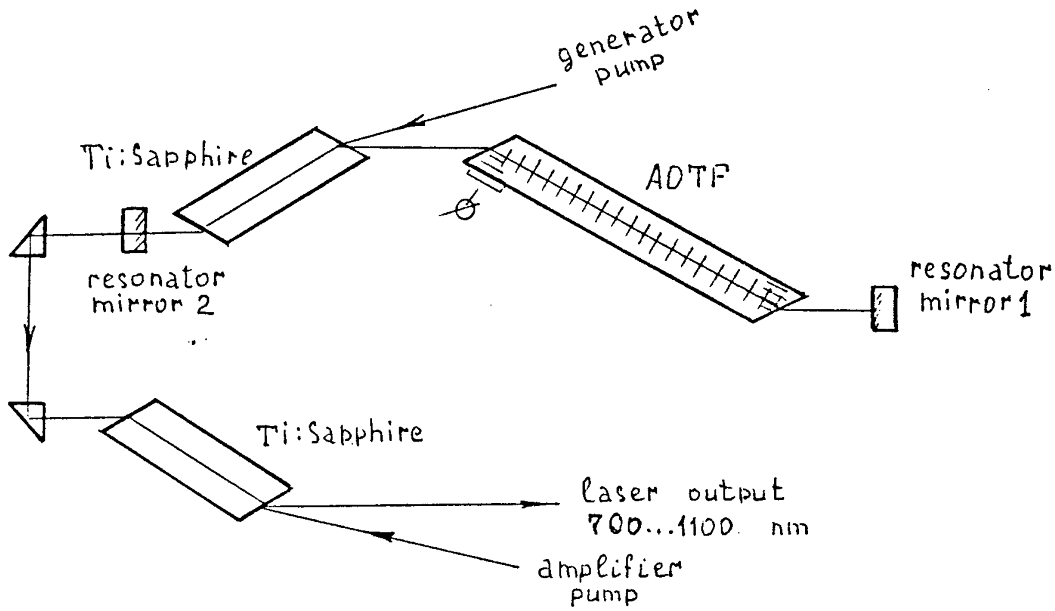
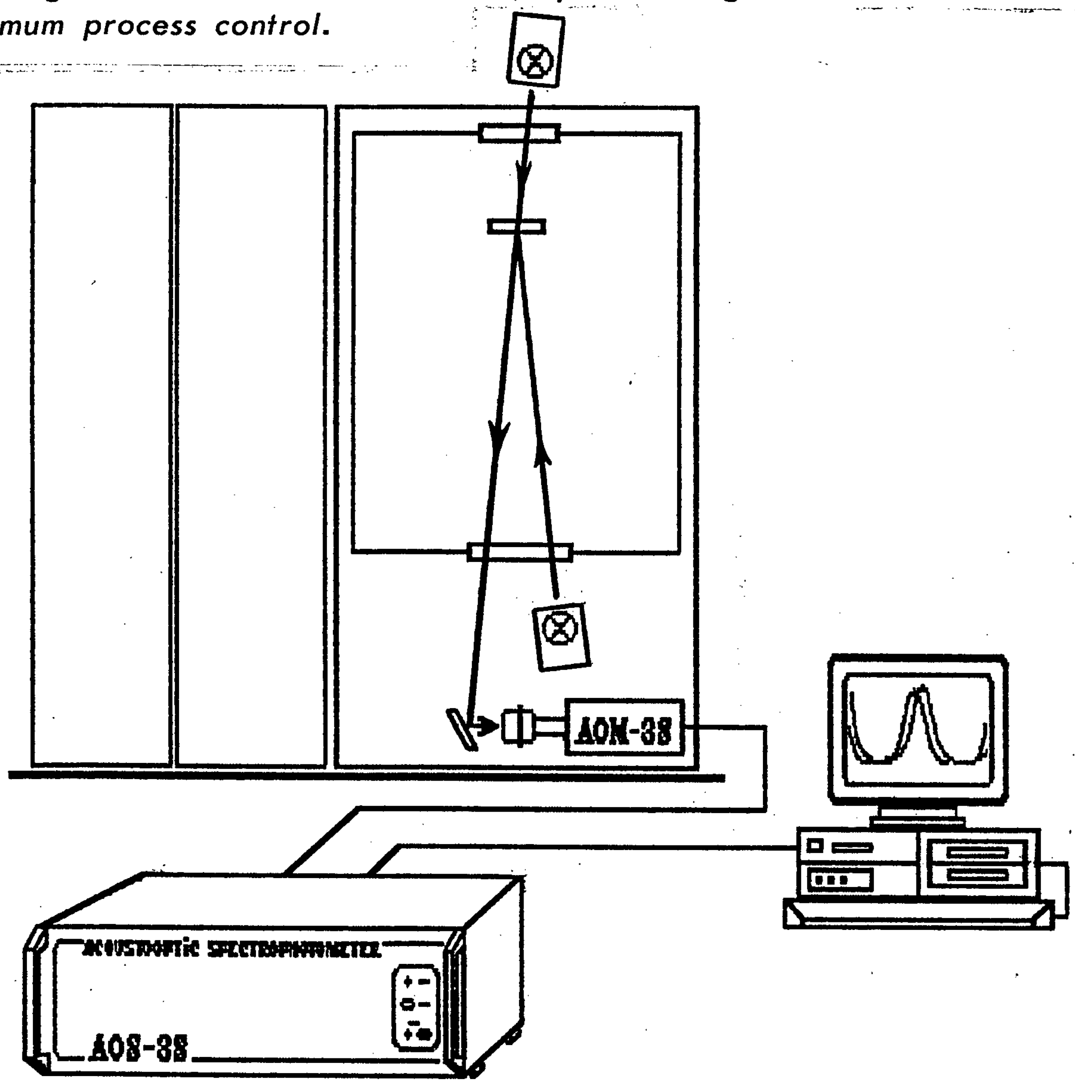


Fig. 2

Fig.2. Optical configuration of a Ti:Sapphire Laser with acoustooptical control of its emission parameters.

ACOUSTOOPTIC SPECTROPHOTOMETER FOR VACUUM DEPOSITION SYSTEMS

Acoustooptic Spectrophotometer is the new high performance device providing inertialess multi-wavelength measurement and rapid scanning measurement of the multi layer coating characteristics for optimum process control.

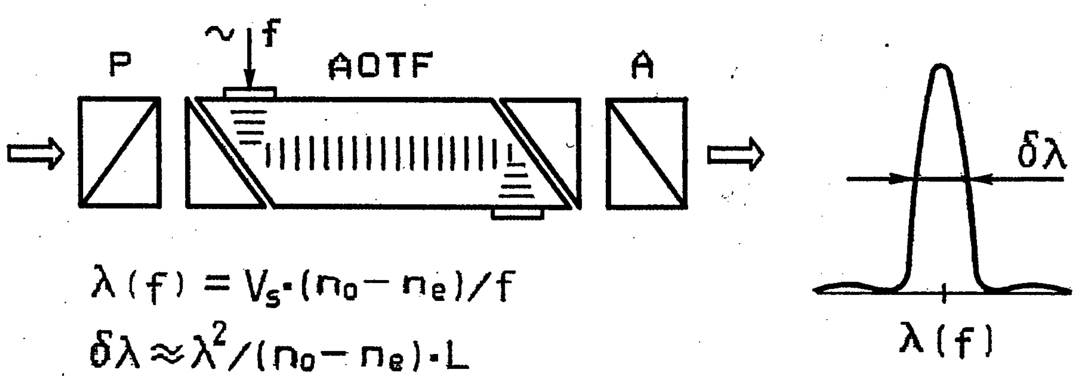


* in-situ real time monitoring of optical film spectral transmitssion (reflection)
* high spectral resolution
* wide dynamic range of photometric signal
* high values of both anqular and linear apertures
* high AM frequency of photometric signal
* absence of any moving details

Description of the Acoustooptic Spectrophotometer

Acoustooptic Spectrophotometer is a new kind of high performance In-Situ Photometer providing inertia-less multi-wavelength and rapid scanning control during the deposition of multilayer thin-film optical coatings.

The major part of the Acoustooptic Spectrophotometer is the high-aperture acoustooptic monochromator based on electronically tunable acoustooptic filters (AOTF). AOTF itself is a synthetic anisotropic crystall in which a diffraction grating is provided by ultrasonic wave; the AOTF wavelenght is determinated by a spatial period of this grating given by RF-signal applied to AOFT piesoelectric transducer **(fig. 1)**. Electronical tuning of this ultrasonic diffraction grating provides inertia-less wavelenght switching (< 1 ms) and high value of AM frequency (up to 5 kHz).



$$\lambda(f) = V_s \cdot (n_o - n_e)/f$$

$$\delta\lambda \approx \lambda^2/(n_o - n_e) \cdot L$$

Fig. 1. Schematic Diagramm of an Acoustooptic Monochromator.

Acoustooptic Spectrophotometer provides all known photometric algorithms of optical film thickness monitoring and process control:

- usual single wavelength algorithms with cut-off after a multiple of $\lambda/4$ has been reached or cut-off when a prespecified reflectance or transmittance value has been reached,
- real-time spectral curves measurement during the deposition process with manual or automatic cut-off,
- high precision multi-wavelenght measurement during the deposition process with automatic cut-off.

Moreover Acoustooptic Spectrophoto - meter provides any combination of these algorithms, for example - real-time spectral curve monitoring with precision single - or multi-wavelenght measurement for automatic cut-off.

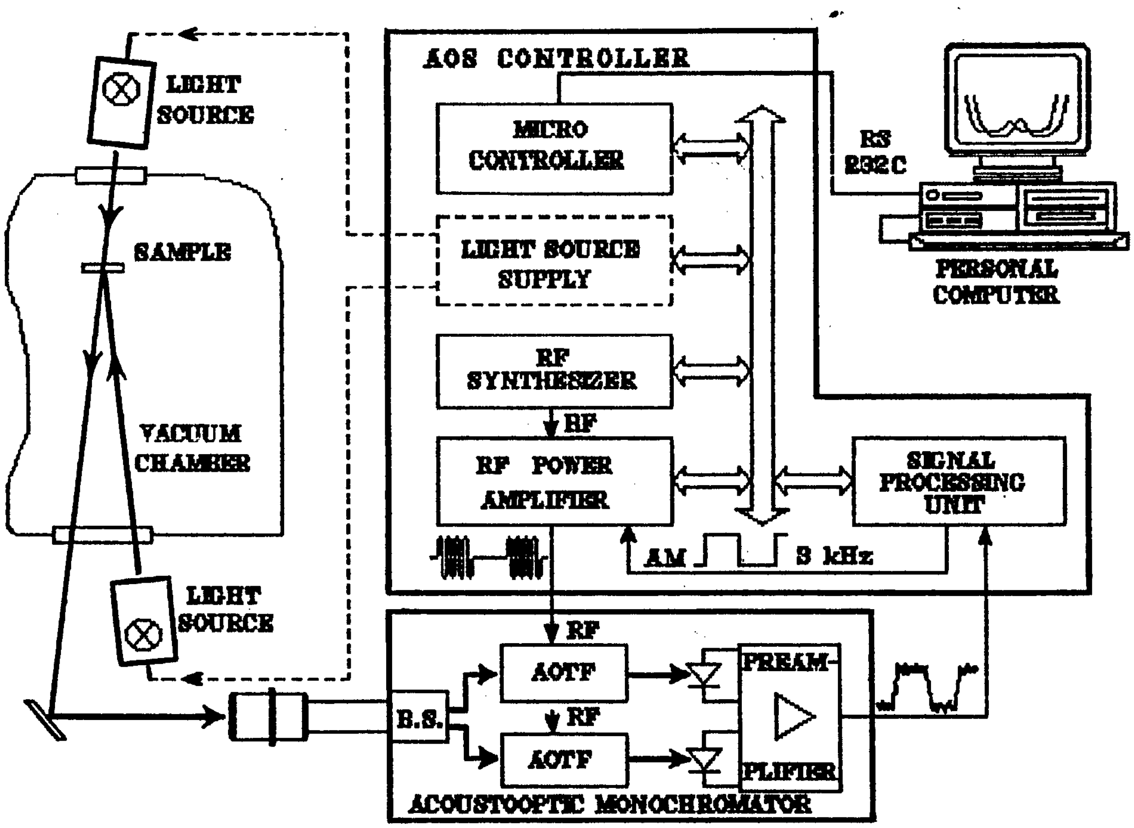


Fig. 2. Schematic Diagramm of the Acoustooptic Spectrophotometer.

The software package takes full advantage of the Acoustooptic Spectrophotometer for optical coatings monitoring and deposition process control. This package includes the next programms:

- programms for data preparing (calculation of spectral curves, simulation of spectral curves evolution during the deposition etc);
- programms for monitoring and control, including the refractive index correction and spectral curves correction;
- programms for diagnostics of the device.

The Acoustooptic Spectrophotometer may be optically connected with any deposition system.

The Acoustooptic Spectrophotometer is specially useful for development and manufacturing of multilayer coating systems with extremely tight tolerances, for example, for bandpass and color conversion filters, achromatic beam-splitters and AR coatings, precision laser optics etc.

T E C H N I C A L   D A T A

* Spectral Range: 370-1175nm, 220-2200nm optional.
* Wavelength Bandpass: at λ=408nm 0.3nm
  at λ=633nm 0.5nm
  at λ=1014nm 2nm
* Wavelength Accuracy 0.2nm
* Minimum Wavelength Tuning Step 0.1nm
* Acquisition Time at a Point no less 5ms
* Photometric Accuracy of Reflectance or Transmittance Measurement S(%) for 40ms Accumulation Time:
  at λ=900nm (0.01+0.01S)%
  at λ=400nm (0.1 +0.01S)%
* Computer Connection Interface RS 232C
* Dimensions,mm see Fig.3,4
* Weigth 25kg
* Electrical Supply: Voltage 190-245V
  Frequency 50/60Hz
  Power Consumption 250VA

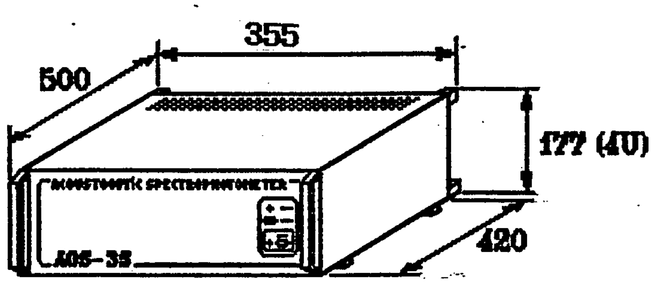


Fig.3
AOS Controller

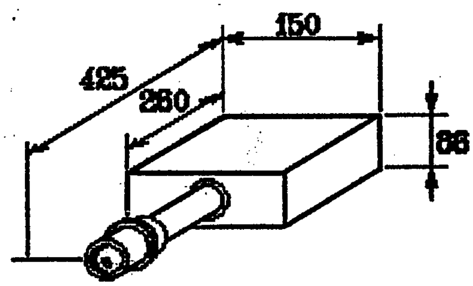


Fig.4
Acoustooptic Monochromator

Pesearch & Development
Institut "Polyus"-"Norma" Co.Ltd.
3 Vvedensky St, 117342 Moscow
Russia
Fax (095) 333-0003
Phon(095) 333-0456

Name:Oleg I.Buzhinskij,Ph.Dr.Head of Laboratory
Address:Line Company Ltd.,Bolshaya Serpukhovskaya,12,
Moscow,Russia,113093
Phone:(095) 334 05 38, Fax:(095) 230 29 00
E-mail: Buzh@fly.triniti.troitsk.ru

DIAGNOSTIC SYSTEM BASED ON COPPER VAPOUR LASER

$\boxed{\text{Gennady V.Abrosimov}}$Oleg I.Buzhinskij,Tatyana S.Pulinets,Alla A.Skvortsova

Copper vapor lasers were used successfuly for investigation of the different physical processes.A Cu-laser generates pulses which duration is $2 \cdot 10^{-8}$ s, whith a high repetition rate (up to 200kHz) and high pick intensity (several tens kW). It emits two wavesλ_2= 510,6 nm and λ_2= 578,2 nm with band width ~ 7,7 GHz. The gain of the active medium is ~ 0,1-1,0 cm ,the average output power ~ 100 W, the divergence is close to the diffraction as an unstable resonator is used.

All these properties permit to use this kind of lasers widely in scientific researches and in technology.

We constructed a Cu-laser based on a serial active element УЛ-102 and a pulse generator using a thyratron ТГИ-1000/25.

The high gain of the copper vapor laser permits to use it in the laser projection microscope. The simpliest schematic diagram of the laser microscope is shown in fig.1. The active medium of the laser is used for the illumination of the investigated object as well as for the amplification of the light beams containing the image of the object.

The magnification of this system is determined by the relation ОП2/ОП1. The active medium must satisfy several requirements.

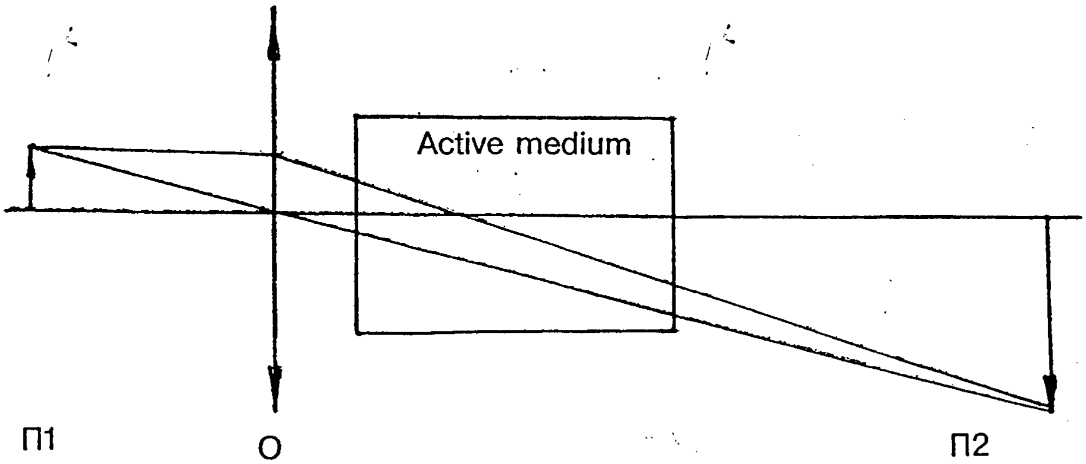


Fig.1.Schematic diagram of the laser projection microscope.

1.The active medium must be optically homogenious in order not to bring distortions into the object image.

2.The one pass amplification of the active medium has to be sufficient to obtain a significant magnification of the image brightness ~ 0,1 - 1,0 cm^{-1}

3.The spacial dimensions and angular aperture of the active medium must facilitate passing of the light beams carrying the object image .

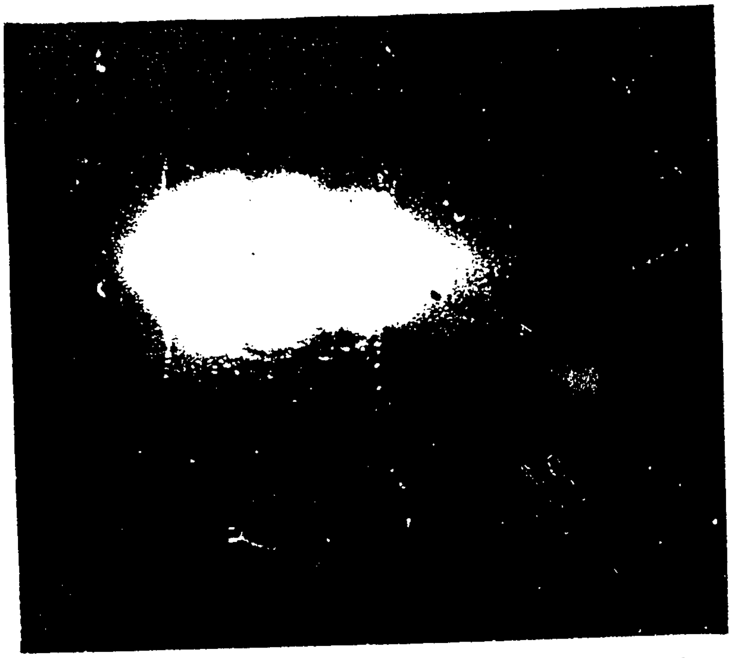
The copper vapor lasers completly satisfy these requirement.

High brightness of the active elements as illuminators of the object and a narrow band of its amplification as an amplifier permit to use a laser microscope for investigation of surface phenomena which have their own high brightness (for example,the brightness of a heated surface,the plasma and the gas brightness in processes of interaction of the lasers radiation with matter).

We applied the laser projection microscope for observation of a dielectric surface between electrods during a sliding spark discharge. The duration of the spark was ~ 1μs,the temperature was ~ $3{\cdot}10^4$K.

The photograph of the discharge gap is shown in fig.2. We can see clearly the electrods and the dielectric surface.

a)



b)

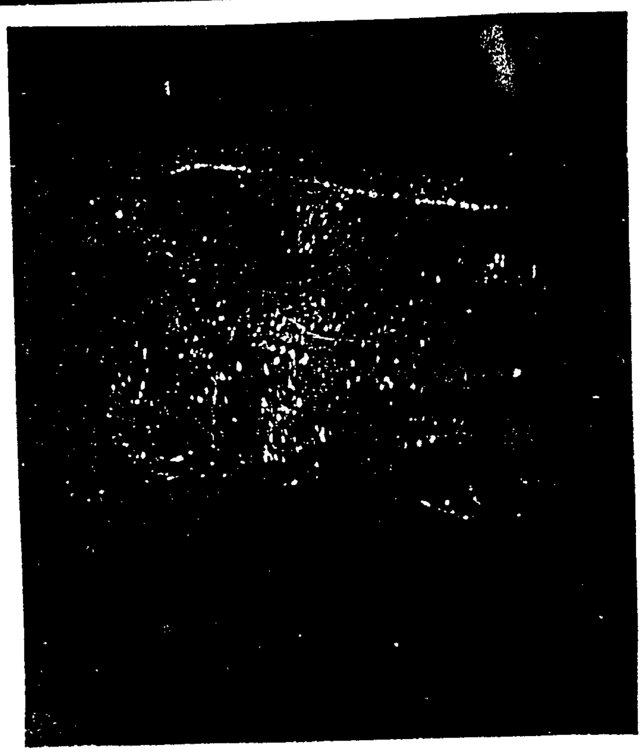


Fig.2.The photograph of discharge gap: a)without laser microscope; b)with using laser microscope.

The processes of the interaction of a high power CO_2-laser radiation with fuzed quartz were investigated. Regardless the high brightness of the interaction region the magnificant image of the cavity at different stages of development has been obtained. If shooting sinchronized with Cu-laser pulses are used the information about interaction processes dynamics may be obtained.

An arrangment for observation of the welding bath and the precise laser beam guiding to make a welding seam visible is an example of the laser projection microscope application.

Application of a powerful laser radiation for material processing is based on the thermointeraction of energy and matter.It is necessary that the density of radiation power be $10^5-5\cdot10^6$ W/cm for the laser weld.Materials are quickly fused and evaporated under the influence of this energy.

The zone of the interaction of the laser radiation with the matter is a source of intensive radiation in the visible and infrared regions. The quality of the weld connection is determined by absence of some defects on the weld seam (pores, nonfuzion) and it depends on the precise laser beam lengthment on the joint. The small diameter of the focal spot requires that the laser beam be directed precisely at the joint during the laser welding. It is difficult to observe the weld process visually

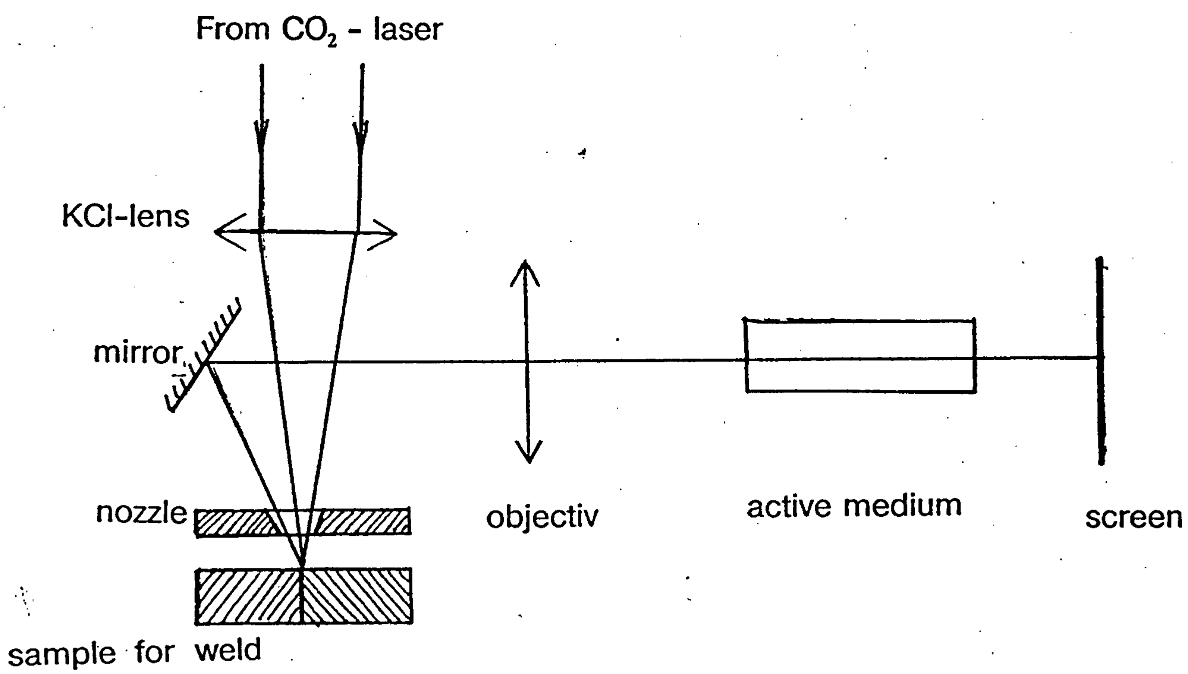


Fig.3.The scheme of the arrangement for observation of the welding bath

a)

b)

Fig.4.The photograph of the welding bath: a)without laser microscope; b)with laser microscope (different focuses).

because of metal and plasma's own brightness is too high. Application of a narrow band filter does not give a necessary result since in this case only a very hot surface is visible.The scheme of the arrangement is shown in fig.3. The focus distance of the objective 5 is 300 mm, the diameter of the nozzle hole 3 is 4 mm,and the magnification of the system is 15. One can receive a clear image of the weld seam on the screen and the processes of the metal motion in the cavity by this apparatus.

The operator can guide the laser beam exactly on the seam during welding processes and this garantees the quality of the weld.

The photo of the laser weld process with and without the laser projection microscope is shown in fig.4.The experements show every prospect of the excellent application of the laser projection microscope for observation of the weld seam.

The interference methods are widely used for investigation of fast processes in a gas flow.The short pulse duration permits to record instantaneous distribution of optical heterogeneity and the high repetition rate of the Cu-laser permits to observe the temporary development of the processes. The Michelson interferometer was used for investigation of optical homogeneity of subsonic and supersonic gas flows.A scheme permits to use the same interferometer also for shadow methods.The interferogram processing gives the information about homogeniety of the gas flow.

Basing on the previous discussion we proposed several diagnostic systems based on a Cu-laser.

1.The system for taking pictures of the interaction region of high power radiation with matter with the exposure time $2\cdot10^{-8}$ s and the repetition rate up to 10^4 Hz.The system can be easely sinchronized with any pulsed process.

2.The system for investigation of processes of the matter being thrown out of the interaction region by means of shadow and interference methods with following computer treatment.

3.The system for the investigation of laser active medium optical homogeneity by shadow and interference methods with following computer treatment.

UNIQUE DESIGN OF SINGLE-MODE CO2-LASER AND LASER TECHNOLODICAL PROCESSES DEVELOPED BY THE "LASERNYE KOMPLEXY"

C.s. A.Grezev, E.Zelenov, A.Morozenkov.

Providing of high homogeneity level of active medium and realization of requirements to resonator optical elements capable of high beam loads are the nessesary conditions for development of profitable single-mode CO2-lasers with increased output power.

Obtaining the needed homogeneity level of active medium is the most stubborn problem because of the negative effect of some interrelated and difficult-to-control physical factors. While production of high quality optical elements is in principle possible by using advanced technologies.

Through abovementioned features the reliable and low-cost industrial laser systems of high beam parameters are not available at the modern laser market despite the R&D activitieson such lasers in many countries.

Employing electrodeless capacitive AC discharge with 12-15 kHz frequency for generation of highly homogeneous medium in diffusion-cooled waveguide tubes with slow pumping may be considered as one way to solution of the present problem.

This unconventional solution used for development of high- power CO2-lasers is associated with two factors:

1. The existing assumption derived from the R&D expirience of single-mode diffusion-cooled CO2-laser with stable resonator proposes not more than 1 kW limiting output power in single mode for mentioned lasers under retaining design compactness and simplicity.

This limit stems from the fact that for physical reasons the power from one length unit of active element of diffusion-cooled laser is independent of element length and limited by 50-70 W/m.

Thus at laser power 1 kW the needed active element measures about 20 m in length. This length increases the negative effect of the heat lens in medium resulting from temperature profile nonhomogeneity in discharge tubes. The need for this lens compensation by retaining laser design compactness calls for great number of controllable reflecting elements with aspheric surface that complicates the laser design and tends to increase in price.

By development of laser with power more than 1 kW the abovementioned reasons caused the abandonment of the diffusion-cooled laser concept in favour of fast-axial/transverse-flow lasers. However the retaining of homogeneous active medium in the latter involves difficulties and plagues the development of high-power single-mode lasers.

2. Waveguide resonators traditionally were used for stabilized tunable CO2 - lasers with power not more than 100 W. They were not discussed by R&D of powerful single-mode lasers even though existing high-power multichannel CO2-lasers, offering an assembly of separate waveguide lasers (50-100 units) with common resonator. However the beam quality of the assemblies is not high and they are used only for heat treatment.

Thus by development of lasers with output power up to 5 kW and more and with high-quality beam parameters the diffusion-cooled laser was not considered as an alternative to fast-flow one. At the same time using electrodeless AC discharge in combination with waveguide beam distribution within discharge elements in diffusion-cooled lasers enables to develop low-cost and easy-to-use lasers up to 1 kW output power with high-quality beam parameters.

Recently the pilot plant of 1,5 kW single-mode laser on the base of existing prototype DL-500 is developed and produced by the Joint-Stock Company "Lazernye Komplexy" and the model with 2,5 kW output power is under development. The authors of the development have established the possibility to design laser system of discussed type with 5 kW output power. The performances of above considered lasers are given in the Table below.

	DL-500 (prototype)	DL-1500 (existing)	DL-2500 (under development)	DL-5000
Nom.beam power, W	500	1500	2500	5000
Min.beam power, W	50	150	250	500
Beam diameter, mm (total)	7	7(14)	14	14
Mode composition Factor, M	<1.1	<1.1	-"-	-"-
Beam divergency, mrad	1.5	1.5(0,7)	0,7	0,7
Required power, kW	5	15	25	50
Gas mix consumption, nl/h	1	3	5	5

The development of technological processes using laser beam as well introduction of laser technologies in different machinery manufacturing are the most significant tasks in the activity of the Joint-Stock Co. "Lazernye Komplexy". By the present more than 115 laser systems (App.1) are put into operation for cutting of various material (different steels, quartz, wood, plastics, etc.). Geography of their location covers besides Russia some countries of the Former Soviet Union, Europe and South-East Asia.

The new technological processes on laser surface heat treatment of machine parts have been introduced at 12 different factories. Using of 5 KW laser system (App.2) for laser welding of stainless steel tubes (App.3) with the system for visual remote control (App.4) at one of the pipe plants enabled to increase the efficiency more than 5 times and twice to reduce the welding cost.

Experts of the company took part in development of technological processes for laser cutting and welding of high-resistance and light alloys, hard-facing of wear-resistance coatings onto surface of parts operating at high temperatures and corrosive mediums such as turbine blades, pipe-line valves, valves of internal combustion engines. In all more than 300 various technological processes of laser welding, cutting, surface heat treatment and hard-facing have been worked out.

APPENDIX 1.

LASER SYSTEM FOR CUTING

Eduipment:

- CO_2-laser;
- two-axis working table;
- external optical path with focusing objective.

Technical date:

Laser rated output power, kW	0.5-1.5
Sheet area, mm	(1.2-3.0)x(1.7-6.0)
Cutting speed, m/min	to 21
Material thickness, mm	up to:

steel	15
non-ferrous alloys	3
wood	180
wood particle board	40
plywood	50
marble	20
Cutting width, mm	0.1-1.0

Features:

* contact free process;
* figure cutting;
* availability to operate within flexible production system.

APPENDIX 2.

INDUSTRIAL CO2 LASER TL-5M

The CO2 laser TL-5M is used for welding of alloyed and carbon steels, non-ferrous metals and alloys, for cutting of metalic and non-metalic materials, heat treatment and surface alloying.

The system TL-5M involves a power supply and a head as a mono-block design.

Gas mixture pumping is performed by high-speed axis blower. DC transverse discharge provides gas mixture exitation. Electrode system consists of segmented cathode and anode plate. An extra high-frequency discharge is used for improvement of discharge homogenity and stability. The beam is formed in unstable con- focal resonator with M = 2.3.

The beam high quality and stability are provided with passive as well as active means. Mounting of resonator mirrors on stiffened slabs fastened by superinvar rods realizes passive stabilization. Active stabilization involves the system for automatic fine-adjustment ensuring uniform beam intensity and the output power stabilization system with an accuracy of 1 %.

Beam axis visibility is performed by He-Ne laser.

Parameters control and laser operation is carried out by control panel in manual and programmable modes.

Features:

* Transverse gas flow discharge
* Compact design
* High beam quality
* Parameters stability
* Microprocessor control system
* Easy-to-use

Design features:

* beam delivery systems
* closed-loop cooling system
* focusing optics
* pulsed operation mode
* remote control system
* technological equipment

Technical data:

Wavelength, m	10.6
Exitation	DC
Nominal output power, W	5000

Power adjustment range, W	500-7500
Long-term stability (at T of cooling water +/- 3C),%	2
Beam diameter, mm	50/22 ring
Beam divergence, mrad	<=1.5 (full angle)
Pointing stability, mrad	<= 0.15

APPENDIX 3.

LASER WELDING OF STRAIGHT-WELD STAINLESS-STEEL PIPES

Applications:

Laser welding is a novel and highly efficient process of producing hogh-quality welded pipes. The technology is advanced as alternative to argon-arc welding.

Equipment:

- tube mill;
- CO2-laser;
- external optical path with focusing objective;
- system for visual remote control;
- joint-traking system;
- system for technical rpocess visual inspection.

Technical date:

Laser rated output power, kW	5
Welding pipe wall thickness, mm	0.8-4
Wilding speed, mm	2-15
Weld wdth, mm	0.4-2

Features:

* narrow "keyhole" weld (weld shape factor accounts for 2-3)
* practically total absence of heat affected zone;
* production of weld joints that remain mechanical properties of base metal snd do not tend to intercrystalline corrosion and corrosion cracking.

APPENDIX 4.

SYSTEM FOR VISUAL REMOTE CONTROL

Designed for visual remote control of technological process. It enables to exercise control over joint, weldpool, weld and jet in natural colours simultaneously.

Features:

- selective filtration by photochroma light filter,
- fiberoptic screens,
- sighting range, mm 35-700
- magnification 1-8
- field of vision, mm 11-92
- weight, kg up to 2,5

2. Laser Technologies.
Лазерные технологии

c. X-ray and Electronic Lasers.
Рентгеновские и электронные лазеры

3. Semiconductors.
Полупроводниковые материалы

a. Non-Traditional Semiconductors.
Нетрадиционные полупроводники.

3. Semiconductors.
Полупроводниковые материалы

b. Thermoelectric Semiconductors.
Термоэлектрические полупроводники.

3. Semiconductors.
Полупроводниковые материалы

c. Piezometallic Semiconductors.
Пьезометаллические полупроводники.

4. Applied Physics.
Прикладная физика

a. High-Temperature Superconductivity.
Высокотемпературная сверхпроводимость

4. Applied Physics.
Прикладная физика

b. Wave Propagation.
Распространение волны.

4. Applied Physics. Прикладная физика

c. Surface Physics. Физика поверхностей.

Practice of Redesign of ex-Soviet Vacuum Machines by Using Imported Components and Subsystems

Oleg V.DUDAR, executive director of "DELFIN-TTT"

JV "DELFIN-TTT Ltd" Engineering Company
Sumgaitskaya str. 13/1, P.O.Box 1615,
Cherkassy-10, Ukraine 257010
tel./fax 0472-669402, tel.0472-651513

This report is addressed to the 1st Commercial Conference of Science and Techniques for the private business of the CIS in the area of High Technologies (Moscow, 22-24 September 1996)

I present this report to the Conference on behalf of "EKITEK-DELFIN" Group of private companies from Ukraine and Spain that are working in the area of *SURFACE ENGINEERING.*

Apart from this paper devoted to vacuum technologies and machinery, we are presenting the following reports to everybody's attention at the Conference:

- a report on laser subjects (material cutting by a laser beam);
- a report about structures of thermally sprayed coatings with a droplet phase;
- a report on "dry" forevacuum pumps that are newly developed by us.

In my paper there are two main messages:

1. Experience of the JV "DELFIN-TTT" in the redesign of home-made vacuum machines with the employment of modern imported components.
2. Progress in the development and manufacturing of "dry" vacuum pumps.

Our activity in the area of vacuum techniques and machinery as well as of any other company of the CIS that is busy with real projects of this kind is the continuation of different traditions, fields of research and a more than half century history of vacuum schools of the ex-USSR, today among their successors there are different institutions, companies and private business of Russia, Ukraine, Belorussia and other countries of the CIS.

1. Theses on the problems of the redesign of vacuum equipment.

- Despite of very interesting, various and, sometimes, unique vacuum technologies our companies and enterprises technically equipped with, the equipment for their implementation is often far from being perfect. Main disadvantages of home-made vacuum machinery are as follows: low reliability in operation; big errors in the control of main process parameters and unsatisfactory technology repeatability; imperfection of obsolete control systems.
- We offer quality-improved vacuum machines as a result of the redesign of ex-Soviet equipment. Main advantages of the new machines are the following: improved reliability and repeatability of coating quality, as well as low manufacturing costs if compared to the Western analogues.
- Basic principles of Redesign:

  - the employment of home-made evaporation sources, vacuum chambers, fittings, and partially pumping stations;

  - full substitution of control systems and blocks for the process control with the employment of imported components, flexible logic, and a Software of our own development.

The redesigned vacuum machines can run in fully automated modes and show high repeatability characteristics for certain technical processes of coatings deposition in vacuum.

- At the present moment, we are making the redesign of an ex-Soviet machine of the VY-2MBS model in one of the technical centres in the Northern Spain. A programme for complex tests and experiments of the redesigned machine is being planned for the 1st quarter of 1997. The machines's designation is to make hard and wear-resistant coatings.
- With the participation of "CEGASA" and "Laminacion Vizcaya" from Spain, we are working under a project of the redesign of ex-Soviet laboratory machine for the deposition of Ni-coatings upon steel strip. According to the programme, in the late 1997 this machine has to be in operation in Eibar, Spain.
- Cost analyses for the redesigned vacuum machines gives a level of the following figures:

  - single chamber machines cost in the range of $120.000-$650.000 depending on modifications in their design and construction (foreign analogues cost in the range of $400.000-$1.200.000);

  - vacuum metallization installations cost in the range of $600.000-$3.500.000 depending on their productivity and a technology range (foreign analogues cost in the range of $3.000.000-$8.000.000).

2. Theses on "dry" vacuum pumps development.

- Since the middle 80's a special attention has being paid in vacuum pumps industry to the development of a new generation of forevacuum pumps of a "dry" type, that produce very pure vacuum and are ecologically friendly. There are proves of this statement in the catalogues of the well-known companies that are pumpmakers, like "Varian", "Alcatel-CIT", "Edwards", "Bazers".
- Our specialists together with the product engineers from the "LBM" private company (Cherkassy, Ukraine) have designed a line of "dry" rotary vane pumps of pumping speeds in the 10-120 m^3/h range and an ultimate pressure of the 15 kPa range as maximum, i.e. 150 mbar (see a technical description enclosed). In the CIS there is no any analogue.
- New "dry" vacuum pumps of the NP-series have a price in the range of $ 210- $ 680, while the analogues pumps of "Busch" (Germany) production cost in the range of $ 830- $ 2380.
- Since Spring'96, we are progressively developing a first model of the line of "dry" rotary vane vacuum pumps of an ultimate pressure in the 5 mbar range as maximum. To our specialist opinion, yet there is no any analogue for such a pump in the world although they are close by their technical characteristics to the widely-used membrane (diaphragm) pumps, but they are likely to be simpler and more competitive.
- Nowadays, we are looking for a strategical partner for a successful implementation of the "EKO-PUMPS'96" Project aimed at the development of a new line of "dry" rotary vane vacuum pumps. We suggest any interested company carrying out a joint development of the new vacuum pumps.

Precision grinding of the
solid by pitch polisher with surface-charged
abrasive.

Abstract.
A model of precision surface treatment of silica glass by a grinding tool on a pitch binder has been developed. The relationships between the material properties (fused silica, diamond abrasive grains) and the controlled parameters of the process have been obtained. Conditions for efficient removal of the damage subsurface layer from the specimen under brittle fracture conditions are presented.

Precision grinding of the
solid by pitch polisher with surface-charged
abrasive.

Yu.N.Lohkov, I.V. Moskalev.
Moscow State Institute of Electronics and Mathematics

The quality of a surface is one of the key factors , determining the performance (service life ,optical damage ,etc.) of optical elements. In order to attain a high-quality surface with minimum roughness and depth of subsurface damaged layer (SDL)) a few stages of finishing treatment are required [1-4]. The choice of the optimum technological regime for these operations is based on statistical experience. However, in order to manufacture surfaces with extremely low roughness and depth of the SDL, the shortest time, the lowest power consumption , the highest good-to-bad optical component ratio the organization of the technological process must be substantially improved. Statistical processing experience is not sufficient for solving this problem in full measure. Therefore the demand arose for development of physico-mathematical models of precision surface treatment. They will form the basis for creating automated technologies, ensuring an optimum regime of surface treatment with specified quality.

The purpose of the present work is to consider a model of microgrinding (MG), i.e., the final stage of mechanical precision surface treatment of brittle materials. A possible sequence of stages of precision surface treatment is presented in the table. The model should give functional dependences for the working hold down pressure of the polisher (grinding wheel) and the removal rate taking into account the physico-mechanical characteristics of the used materials as well and the controlled parameters of the technological process . We will consider on the example of quartz glass microgrinding by a surface-charged abrasive tool. The evaluation of the MG parameters will be based on the following data:

Physico-mechanical characteristics of quartz.

Young's modulus, $8\cdot10^{11}$ dynes/cm^2
Shear modulus, $3\cdot10^{11}$ dynes/cm^2

Controlled parameters

Pressure exerted on the polisher , $2\cdot10^{4}$ dynes/cm^2
Density of the abrasive grains , $2\cdot10^{4}$ grains/cm^2
Sliding velocity of the grain, 20 cm/sec
Mean radius of grain, 4 μm
(for the grit size Russian designation , micron 5/3)

Optimum organization of the microgrinding process. The main purpose of the microgrinding stage is to reduce the roughness and the thickness of the subsurface damaged layer preserved after the previous surface treatment (fine grinding) during the shortest time and with lowest energy consumption . The use of an abrasive in the form diamond ovalized grains (created by a special heat treatment) [5] provides a specimen the with high-quality surface. For example, application of this abrasive ensures minimal amount of the microscratches (created by small wear debrises of the grain) per unit area of the treated surface. The abrasive grains are fixed by a pitch matrix and evenly distributed (with a specified density N grains/cm^2) over the surface of polisher [6]. This is a necessary condition for controllability of the surface treatment. Addition of new grains in the course of operation leds to uncontrollable fluctuations of the main technological parameter P/N.

If the treatment is conducted predominantly in the brittle fracture regime, the power consumption is reduced , because in this case the major portion of elastic energy is spent on the formation of new surfaces (dispersion of SDL) without much dissipation into plastic flow of the material). The brittle fracture is realized , when the interaction time in the contact zone (abrasive grain-treated surface) is less than $t_i=10^{-6}$ sec (for $t>t_i$ the plastic flow can play a significant role in the fracture as has been shown experimentally in [7]).The contact circle (formed by interaction between the sliding grain and the surface) displaces at a velocity V.The size of the region of maximum mechanical stresses field created by a grain in the specimens is aproximately equal to 2a. (a is the contact radius in Hertz's relation [8,9]). Then the time of mechanical interaction between grains and local zone of surface is

$$t=2a/v$$

where $a=(PR/NE)^{1/3}$

It follows immediately that the lowest optimal sliding velocity of grains is

$$V=2(PR/NE)^{1/3}/t_i$$

In other words, V is the critical velocity of the transition from ductile abrasion to brittle abrasion. For quartz V is about 20 cm/sec. Note that the regime of low friction in the contact zone ($\varkappa<1\%$ in the presence liquid oil) also promotes a decrease in energy loss [10].

The analysis of the movement of the abrasive particle into liquid oil[1] showed that the transition from boundary lubrication (with high contact friction) to liquid lubrication occurs, when

$$V>V2\simeq(NE/PR)^{2/3}2(h)^3E/3\pi\eta\simeq10cm/sec$$

$h\cong10\div15\mathring{A}$ is thickness of the water near-surface layer (with

[1] We used simplest hydrodynamic Reynolds model.

elevated viscosity $\eta \cong 0.5 gr/sec \cdot cm^2$). In this case the contact interaction between an abrasive grain and near-surface water layer (with elevated viscosity η) is absent.

Model of the abrasive wear.

We consider a MG process on the basis of the model of wear particle formation in the brittle fracture of the SDL in one pass of the grain. The model makes it possible to determine the lowest hold down force (P/N) for formation of the wear particles and estimate the wear rate and roughness of the treated surface. Let's consider that the main cause of wear particle formation are microcracks, created by the dislocation pileups with a critical dislocation density. They are formed in the region of maximal mechanical stress fields created by abrasive grains . One of a wear particle characteristic sizes is determined by such a microcracks. Consequently, the microcrack formation is also a necessary condition for occurence of the MG process.

We will consider the mechanical stresses distribution on the basis of Huber's relation [9,11]. The contours of the maximal shear stress created by a spherical indentor (a diamond particle) are shown in Fig 1. The maximal shear stresses distribution over OZ (a normal to the surface passing throuh the center of the indentor (Fig 2)) are determined as

$$\sigma(z)=\frac{3P}{4N\pi a^2}\left(\frac{1.5}{1+(z/a)^2}-(1+v)\left(1-\frac{z}{a}\arctan(a/z)\right)\right) \quad (1)$$

where v is Poisson's ratio.

The maximal shear stress τ_{max} at the depth of a/2 (the point O') determined by :

$$\tau_{max} \simeq 0.5\sigma_{cp} \cong 0.5P/(N\pi a^2)$$

It is pertinent to note, that the given stresses distribution is adequate only for a small friction coefficient ($\chi \leq 0.27$) [9] .In this case the effect of the friction forces on the stress field can be neglected.

Fracture of the SDL layer (more ecxactly formation of microcracks, which initiate the wear particle formation at depth of a/2) is considered on the dislocation theory basis. The macroscopic approach (like the model of Hertzian cone cracks) is unsuitable in our case, because estimates (for the given conditions of grinding) showed that the critical Hertzian load is much greater then a normal work load on the indentor during the MG process [11].

According to our model the stages of the process of the microcrack formation are as follows: the formation of the vacancy solution (in the treated material) with high vacancy concentration in the zone of the maximal shear stress created by the abrasive grain → vacancy cluster formation → transformation of the vacancy clusters into the dislocation loops → the formation of the dislocation pileup with critical dislocation density → the microcrack formation.

There we will consider the last stage of microcrack

[2] The exact estimation of the viscosity η is absent (for a different estimates $\eta \cong 0.1 \div 1$ gr/sec·cm).

formation. In the region of the maximum shear stress a loop dislocation arises (for example, by Frank's mechanism [12]). Under shear stresses it expands attaining a certain radius. It can be defined, for example, as the distance from the center of the dislocation loop to an obstacle(like a grain boundary). During the time of contact interaction dislocations produced by multiplication source accumulate near the obstacle. The dislocation pileup acts as a local stress concentrator. The force, acting on the obstacle is expressed as $F0=\sigma bn$, where b is the Burger vector, n is number of the dislocations in the pileup.

When n grows to $n_c \simeq \frac{G}{2\pi\sigma(z)}$ (where G is the shear modulus) the local stresses becomes compartable to the shear strength. This leads to microcracks nucleation (for example, by Zener-Stroh's mechanism [13]). The condition for formation of critical dislocation density has the form

$$L > L_{CT}$$

where $L \simeq \frac{Gbn_c}{2\pi\sigma(z)}$ is the length of the pileup [12]

L_{CT} is the distance from center point (O') to the obstacle. ($L_{CT}=a$, when $L_{CT}>a$)

It follows from this conditions, that the minimum value of (P/N) which a microcrack is formed in the region maximal shear stress field at the depth of a/2 is

$$(P/N)_c=\left(\frac{R}{E}\right)^2\left(G\sqrt{\frac{b}{L_{CT}}}\right)^3 \qquad (2)$$

For quartz $(P/N)=(1\div2)$ dyne/grain, $b=5\cdot10^{-8}$ cm).Note that L_{CT} may be defined as the characteristic distance between dislocation pileups remained after the previous stage of surface treatment.

The wear rate U is defined as the depth of the specimen removed from a unit area in a unit time. The sizes of the wear groove created by the abrasive grain is characterized by a width of 2a and thickness of a/2. Then the wear rate under the condition of brittle fracture in one pass of a grain is

$$U \simeq (PR/ENp)^{2/3} VNp$$

where Np is the number of working diamond grains per unit area [14] . According to more exact estimation (in view of wear rate saturation phenomena (for **N** and **V**)) the wear rate is

$$U \simeq a^2 N_m[1-\exp\{-N/N_m\}] V_m[1-\exp\{-V/V_m\} \cong 600 \text{ Å/sec} \quad (4)$$

where $V_m \cong (L/\tau)$ is microcrack opening displacement velocity, where $\tau \cong 10^{-7}$ sec(for the given conditions of the MG (τ is the time of formation of the dislocation pileup with the critical number of dislocations)).$N_m \cong e/(2a\cdot 1cm)$ grains/cm^2 (the greatest possible density of the working abrasive grain^3)

Let's consider, that the roughness after one grain pass is created by shear microcracks. Such microcracks are formed from dislocation pileups with critical density and are opened at the depth of about a/2).Then the peak-to-valley ratio is

$$K=a/2$$

It is known, that rms= K/4 [15]. For quartz rms=50-80 μm.

Conclusions

In the model of MG discussed above removal of the SDL is occurs by a brittle fracture mechanism and luquid oil regime. The mechanical stress (in the specimen) is created by a spherical punch (diamond) acting with a normal force (P/N) on the treated surface . Microcracks are produced by the action of the shear stresses at a depth of a/2. In this way the grains , independently acting create a particle of wear and the depth of SDL is reduced accordingly. For example the depth of the SDL of the quartz glass may be reduced from 2-3 (initial value) up to 0.2-0.3 μm.

The data of the present investigation will make it possible to finds the ways for developing an optimum process of the high-precision grinding of different glasses and ceramics.

Table

Technological stage	Main aim	Processing mechanism	rms (Å)	h (Å)
Fine grinding (by the multiple-pellet diamond grinding tool)	Decrease in rms and h*	brittle fracture of the damage layer**	120-150	2-3***
Ultrahigh-precision grinding (microgrinding by bounded abrasive tool)	Decrease in the h	Predominantly brittle fracture in conditions of low friction (luquid lubrication)	70-90	<2000
Preparatory (rough) polishing (with CeO_2 powder bounded resin disk)	Decrease in the rms and h	Plastic wear under boundary lubrication regime	20-25	100-150

* minimal roughness and thickness of the subsurface damaged layer (after optimal processing mechanism)

** The change of pressure and/or spindle speed can alter the grinding mechanism [16].

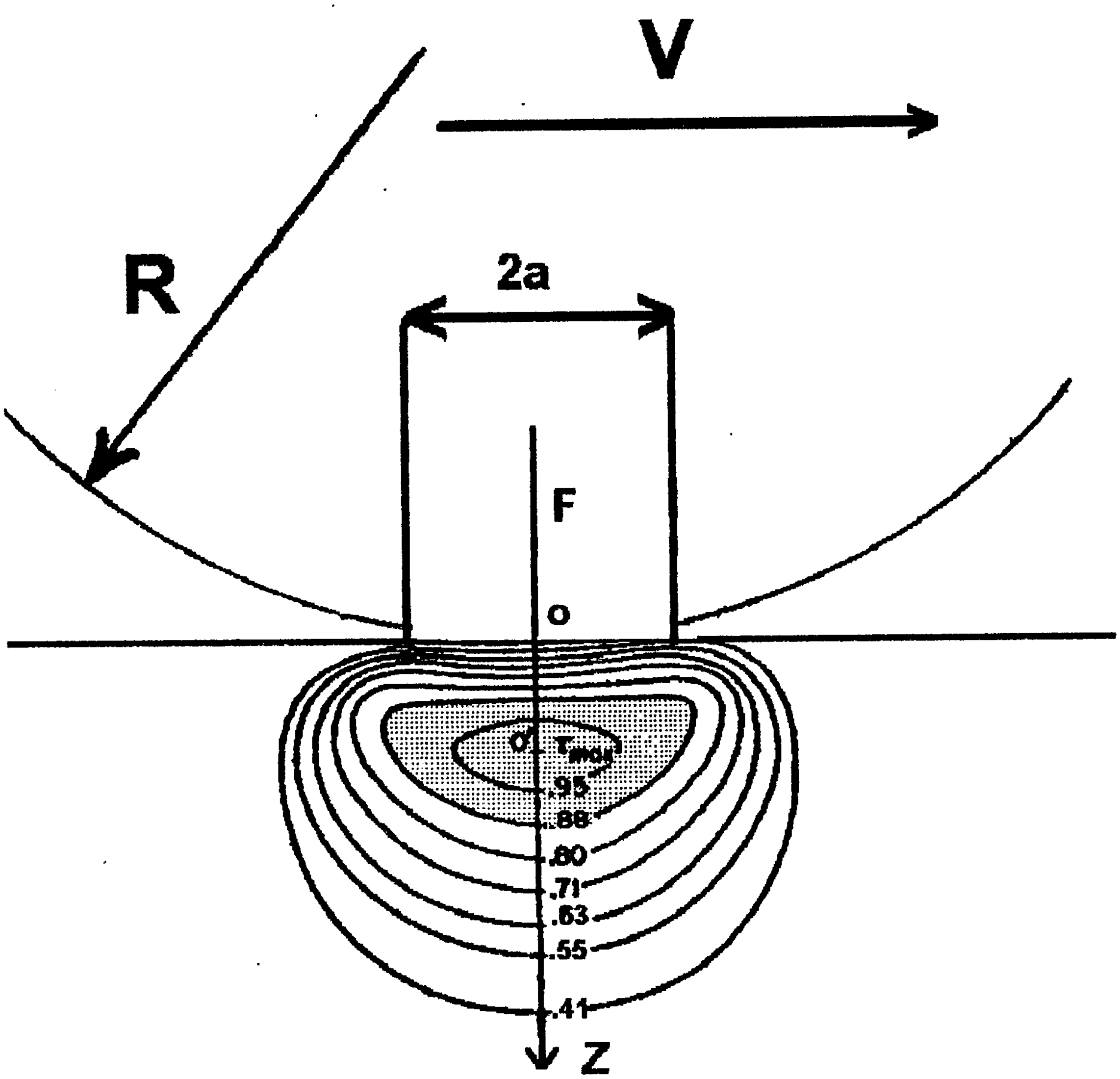
*** In micrometers.

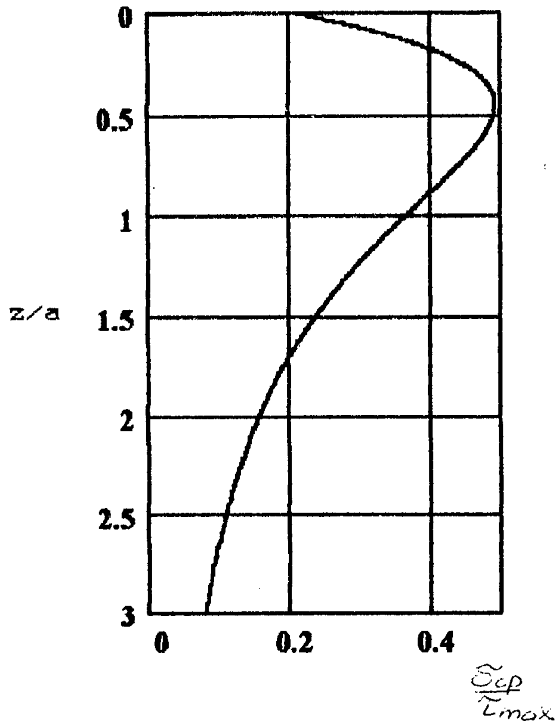
Fig .1. Contours of the maximal shear stresses in the specimen (created by spherical indentor acting with a normal force F=P/N on the surface).

Fig.2. Distribution of normalized maximal shear stresses along the OZ-axis (ν=0.2).

References

1. N.G.Brown. Some speculations on the mechanism of abrasive grinding and polishing // Precision Eng. - 1987. - V.9.- N:3. - P.129.
2. G.M.Sanger. Perspective on precision ,machining, polishing, and optical requirements // SPIE.- 1981 .- V.306.- P.90.
3. A.L.Ardamatskey . Diamond treatment of optical components . [in Russian] Leningrad : Machinostroenie , 1978 - 230 s.
4. G.S. Chodakov.,N.L.Kydravtseva. Fhysico-chemical processes of optical glass polishing [in Russia]. Moscow :Machinostroenie 1985. - p 221 .
5. S.A Klevtsyr,M.R.Spasskii,and Yu.N.Lokhov "Thermal ovalizing of diamond powders" //Izvestiya Akademii nauk SSSR. Neorganicheskie materialy. - 1981.-Vol 17. - N:6. -p.985.
6. M.R. Spasskiy ,Yu.V. Ashkerov ,Yu.N.Lochov Wear and maximum rouhness of metal surface polished by a bond abrasive // Poverchnost' - 1987. - N:2.- P.135-142.
7. V.A.Bernstain .Mechanohydrolytic processes and the strength of the solids [in Russia]. Lenigrad :Nauka , 1987 .- p 318.
8. L.D. Landau and E.M.Lifshits .The theory of Elastisity [in Russian] - Moscow : Nauka ,1987.- p 247c.
9. G.M. Hamilton , L.E. Goodman L.E. Stress Field Created by a Circular Sliding Contact // J.Appl.Mech.-1966.-N:33.- P 371-366.
10. I.V. Moskalev .Model of quartz microgrinding.// Abstr.Rep. of conf. at Moscow State Institute of Electronics and Mathematics [in Russian] . Moscow : 1994 .p 2
11. Yu.V Kolesnikov ,E.M.Morozov Mechanics of contact fracture.[in Russian] -Moscow : Nauka , 1987.- p 381.
12. J.R. Hirth and Jens Lothe . Theory of dislocations . McCraw-Hill Book Company. New-York . 1970.
13. A.N.Orlov .Introduction to the crystal defect theory. - Moscow [in Russian] : Vysshaya shkola ,1983. -p 144 .
14. I.V. Moskalev . The processes of the abrasive wear of the solids . // Abstr.Rep. of conf. at Moscow State Institute of Electronics and Mathematics [in Russian] . Moscow : 1995 .
15. E.I.Church . Models for the finish of precision machined optical surfaces // SPIE. - 1986.- V.676. - P. 142.
16. Gib-Horng Chen . High Speed Fabrication of Aspherical Surfaces, University of Rochester , Rochester , New York PhD . Thesis , 1977 .


V
R
2a
F
o
o'
.95
.88
.80
.71
.63
.55
.41
Z



z/a
0
0.5
1
1.5
2
2.5
3
0
0.2
0.4
$\frac{\tilde{\sigma}_{cp}}{\tilde{\tau}_{max}}$

LINE COMPANY LIMITED

High Speed Photography and photonic Center

113054 Moscow, Stremyannii per., 29

Fax: (095) 230-29-00

Telephone: (095) 237-29-83

HIGH SPEED STREAK AND FRAMING CAMERAS WITH REFLECTING OPTICS

LINE COMPANY LIMITED AND HIGH SPEED PHOTOGRAPHY AND PHOTONIC CENTER develop new high speed streak and framing cameras with reflecting optics. A set of our instruments gives you a possibility to study the world of fast events not only in the visible but in the infrared and ultraviolet spectral bands as well.

TYPICAL APPLICATIONS

- Analysis and control of spatial-temporal and spectral characteristics of IR and UV laser radiation (CO, CO_2, YAG:Er, eximer etc).
- High sensitivity IR - diagnostics of plasma with Schlieren and interference methods.
- All applications typical for visible band high speed analysis.

OPERATION

All devices has control module and scene/time code marker. Continuous-access and event-synchronized mode are obtainable. Optional are spectral attachment, micro and macro object matching lens.

MAIN SPECIFICATIONS

Parameter	Unit	Framing camera mod.201	Streak camera mod. 101	Framing camera mod.202	Streak camera mod.102	Framing camera mod.203	Streak camera mod.103
Spectral band	m	0.3-10.6	0.3-10.6	0.3-4.0	O.3-4.0	0.3-10.6	0.2-10.6
Maximum framing range	x10 f/s	200	-	200	-	500	-
Scanning speed	mm/ s	-	3.2	-	3.2	-	60
Total number of frames		50	2	50	2	50	2
Focal length	mm	250	250	250	250	235	2500
Dynamic spatial resolution in visible band	mm	40	40	50	45	60	25
Effective aperture		f/15	f/17	f/15	f/17	f/15	f/60
Continuous access (*) or synchronization (+) mode		*+	*+	*+	*+	+	+
Electric (*) or turbine (+) drive		*	*	*	*	*+	*+
Weight	kg	80	75	140	90	120	25
Dimensions (WxHxD)	cm	100x70x30	150x80x40	110x110x80	130x100x50	140x110x42	125x42x36
Mains			220V x 50(60)Hz				

LEGAL ADDRESS
Company "Line Co.LTD"
Stremyannii per., 29
Moscow, Russia
Tel. (095) 237 29 83
(095) 237 85 70
FAX (095) 230 29 00
Bank Account
BANK OF NEW YORK, One Wall street,
New York, n.Y. 10286,
USA CHIP VID number 333508, account No 890-0086-092
сч. No 9070980

President
Company "Line Co.LTD" Trofimenko V.V.

Diagnostic complex for temporal and spatial measurements in tokamak

Oleg I.Buzhinskii, Sergey N.Tugarinov, Englen A.Azizov, Vladimir V.Trofimenko, Nikolai N.Naumenko

TRINITI, Troitsk, Moscow reg., Russia 142092
(VVT) Line Company Ltd., Moscow, Russia 113033
(NNN) Institute for Physics, Minsk, Belorussia 220114

ABSTRACT

The diagnostic complex presented includes two stigmatic spectrometers for the visible, close UV and IR region with electronic registration [1]: a) the high resolution spectrometer: wavelength range 200-800 nm; light throughput f/3; dispersion changed in the range 0.15-2.5 nm/mm; image intensifier in 5×10^4 times; spectral channel number - 512; spatial channel number - 8; time resolution 1-100 msec; the best spectral resolution - 0.01 nm; dynamic region 4×10^3 ; b) survey spectrometer: full wavelength range 200-850 nm (for simultaneous registration: 380-850 or 200-400 nm); f/N - 3; image intensifier in 5×10^4 times; time resolution 20-1000 msec; spectral resolution - 0.2 nm; dynamic region 4×10^3.

This complex was used for diagnostic measurements at the TSP and T-11M Tokamak (Russia) and for investigations in the divertor region of DIII-D Tokamak (USA). The results of this measurements are presented.

Key words: spectrometer, Tokamak, line profile, plasma.

1. INTRODUCTION

Spectroscopy in the visible, close UV and IR region is one of the most important diagnostic for the investigations of the Tokamak plasma parameters. The presented diagnostic complex allows to measure the width of spectral lines, shift of line center, splitting value of the line profile. Simultaneously the complex allows to registered spatial distribution of radiation and time history of line intensity. Thus, the complex makes possible to measure such plasma parameters like ion temperature distribution, plasma rotation velocity, impurity density and distribution, value of total magnetic field and under some special conditions - value of electrical field.

2. DESCRIPTION OF SPECTROMETERS

A High resolution spectrometer based on a auto-collimation triple dispersion optical scheme. This spectrometer is shown in Fig.1, where the components by numeric label are: 1 - entrance slit; 2 - spherical mirror; 3 - flat mirror; 4 - corrector element; 5 - first grating; 6 - second grating; 7 - deflector mirror; 8 - image intensifier; 9 - photocathode; 10 - microchannel plate; 11- 2-D CCD detector. An off-axis auto-collimation optical scheme in which the entrance slit and its

image lie symmetrically displaced a small distance from the optical axis of the spherical mirror permits elimination of astigmatism; a quartz correction element compensates for spherical aberration. The shot focal length (370 mm) of the spherical mirror makes it possible to obtain high light throughput (f/number = 3) and triple pass diffraction on

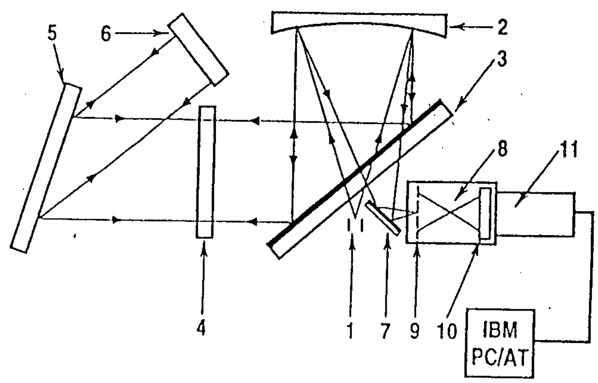


Fig.1. High resolution spectroscopy

gratings with 1800 and 2400 gr/mm gives high dispersion (0.3 nm/mm) despite the instrument's short focal length. The dispersion can be changed over the range 0.3-2.0 nm/mm by using the first grating in single pass. A useful wavelength range is 200 - 800 nm.

The image intensifier consists of an electrostatic inverter and microchannel plate (MCP). The total gain of the intensifier amounts to $(3\text{-}5)\times10^4$ and spatial resolution 20-25 mkm.

The 2D detector head consists of a Peltier cooled CCD matrix with electronic readout, amplification circuitry and analog-to-digital converter. The active area of the matrix is 280×512 pixels; each pixel is 25×17 mkm. During readout of the matrix 35 consecutive scan lines are summed to yield eight horizontal stripes of 512 pixels each, this stripes correspond to division of the spectrometer's entrance slit height into eight spatial view channels. From the detector head the data goes directly into an PC486 where it is stored in RAM memory. The readout time of 7 ms for a single image frame.

A Survey spectrometer based on a stigmatic, high optical throughput (f/3), Rowland-circle spectrograph [1], which provides simultaneous registration of the visible spectrum over the region 400-900 nm with a resolution of 0.2 nm. This spectrometer can be used for simultaneous registration of the wavelength range 200-400 nm with the same resolution by changing a gratings. Fig.2 is an optical schematic of the spectrometer, where: 1 - entrance slit; 2 - flat mirror; 3 - turret with three curved interchangeable gratings; 4 - curved image plane; 5 - diaphragm selector; 6 - trap for zero order of light. For the 1200 gr/mm grating the 140-mm long curved input tip of the fiberoptic transformer intercepts the diffracted light between 400 and 900 nm, this 500 nm spectral swath is spread across twenty fiber conduits which are geometrically rearranged at the output tip of

the transformer into a rastered rectangular array 6.7 mm wide by 13 mm high. A transfer lens assembly relays this image onto the face of the CCD sensor.

The 2-D detector used in this spectrometer is a Wright Instrument CCD camera with Peltier-cooled sensor operated in frame transfer mode. The image area of the sensor consists of 298×576 pixels, each pixel being 22.5 mkm square. The insertion of a photographic mask in front of the fiberoptic transformer permits the selective attenuation of bright lines, thereby avoiding crosstalk between tracks due to saturation.

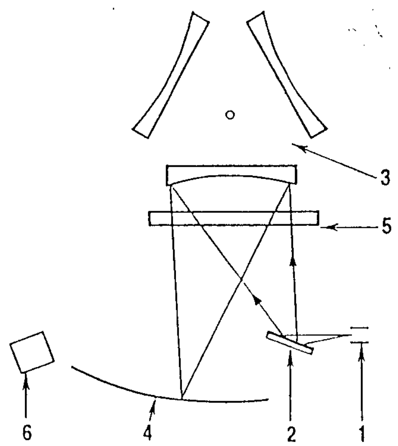


Fig.2. Survey spectrometer

3. RESULTS OF MEASUREMENTS

The main result of our investigations with using High resolution spectrometer's was the measurement of temperature for the CIII ion and D atoms in the divertor region of the DIII-D Tokamak, General Atomics, USA. Viewing geometry in DIII-D is shown in Fig.3, where: 1 - graphite tiles; 2 - inner wall of DIII-D vacuum vessel; 3 - MHD flux surfaces; 4 - divertor baffle plate; 5 - divertor cryopump; 6 - biasable dirertor ring; 7 - port containing DIMES probe. With the four viewchords aimed through the X-point of a single-null configuration, Doppler profiles were recorded for the CIII 464.7 nm and Da 656.1 nm lines, during L-mode, H-mode and "radiative" divertor condition. For reducing the contribution of Zeeman splitting to broadening of the line profile, we used a polarizing filter which selected just the p components of the Zeeman manifold. The typical line profile for CIII triplet and D_α line are shown in Fig.4. The ion temperatures determined from the doppler broadening of the CIII ion in the region below the X-point was found to be 10-15 eV during ELMing H-mode and reduced to the value 6-8 eV during "radiative" divertor condition. D_α line profile usually is multigaussian with the average temperature 1.5-2.5 eV.

Spectroscopy measurements temporal and spatial behavior radiation of impurity have been carried out with a survey spectrometer. At Fig.5 are shown the typical time history and spatial distribution for D_α line radiation. Simultaneous recording of low charge states of carbon, oxygen and injected impurities has yielded information about gas recycling, impurity behavior at the divertor strike points and to characterize the sputtering behavior of candidate first wall materials under actual divertor conditions. Transport of lithium to the divertor region during lithium pellet injection has been studied, as well as cumulative deposition lithium on the divertor targets from pellet injection over many successive discharges [2].

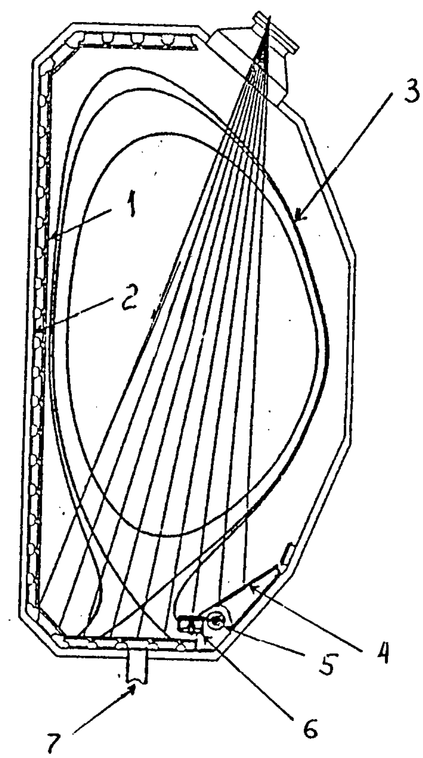


Fig.3. Viewing geometry DIII-D

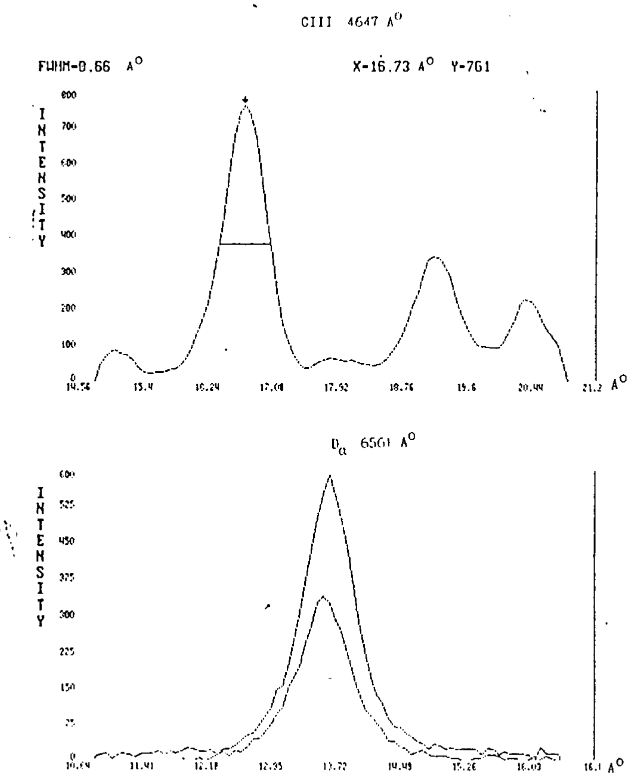


Fig.4. Line profile for CIII triplet and D_α

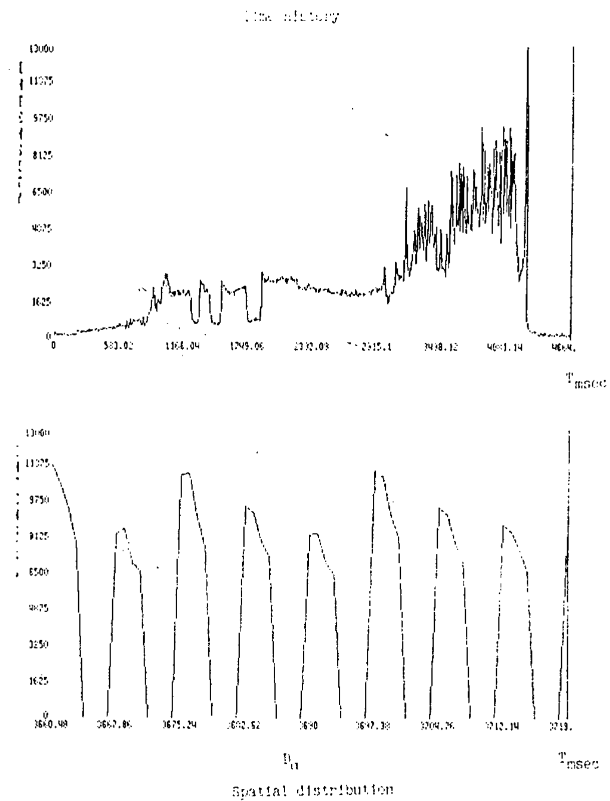


Fig.5. Time history and spatial distribution

4. REFERENCES

1. S.Tugarinov et. al., *Rev.Sci.Instrum.*, 66, p.603, 1995.

2. N.Brooks et. al., "Visible Spectroscopy in the DIII-D Divertor", 12th High-Temperature Plasma Diagnostics Conf., Monterrey, CA, USA, 1996.

Name: Oleg Buzhinskij, Ph.Dr. Head of the Laboratory
Address: Line Company Ltd., Bolshaya Serpukhovskaya 12, Moscow, Russia, 113093
Phone: (095) 334-0538, Fax: (095) 230-2900
E-mail: buzh@fly.triniti.troitsk.ru

Technology of in-situ Deposition of Boron-Carbide Films from Carborane Precursor.

Oleg Buzhinskij and Yuri Semenets

Thin boron-carbon a-B/C:H films obtained by plasma chemical vapor deposition from carborane precursor are widely used for protection of the first wall of fusion devices (so called "boronization") to suppress oxygen, carbon, and heavy (e.g. Fe, Ni, Cr, etc.) impurities and improve characteristics of tokamak discharges [1-4].

During deposition process, a dc glow discharge in a noble gas is initiated in a vacuum vessel. A boron-containing gas, produced by the heating of the container with solid at room temperature carborane $C_2B_{10}H_{12}$ or deuterated carborane $C_2B_{10}D_{12}$, is allowed to flow into the vessel, and molecules are ionized in the discharge. The ions diffuse through the positive column and are accelerated in the cathode sheath. The kinetic energy of an ion-cathode collision under the cathode fall (200-300V) is greater than binding energy, so the ions dissociate and species are included in surface reactions, resulting in the formation of a film on the surface of the cathode.

There are another substances that are used for boron-carbon film deposition: diborane B_2H_6 and deuterated diborane B_2D_6, but these are explosive and highly toxic gases demanding special precautionary measures and equipment. Less toxic and hazardous, but still having a tendency for spontaneous combustion on contact with air, are borontrimethyl $B(CH_3)_3$ and borontriethyl $B(C_2H_5)_3$. Decaborane $B_{10}H_{14}$ is a stable solid at room temperature and is less toxic than diborane. But, unlike these substances, carborane is not hazardous.

Typical film thicknesses are of the order of some hundred nm. The deposition rate is independent of temperature in the range between 50-250°C and time and amounts to 150-200 nm/h.

Coatings exhibits good adhesion to stainless steel, Mo, graphite and silicon. At the present time, it appears that elevated substrate temperatures during boronization are useful primarily to reduce the hydrogen content in the film, but not for any other properties, such as adhesion, etc.

The main species present in the coatings are boron, carbon, and hydrogen (deuterium). The coatings may contain oxygen in quantities of as high as 10%. In addition, metals sputtered from the vessel components at the beginning of the boronization process may also appear. Ordinarily, the coatings contain from 20-50% hydrogen. The hydrogen concentration can be reduced by elevating the substrate temperature and by controlling the glow discharge parameters during boronization. After boronization, the hydrogen concentration can be reduced by He glow discharge conditioning.

The significant value is the ratio of the boron and carbon (B/C) concentrations in the film. This depends on many factors, such as the amounts of B/C in the gas mixture, gas pressure, gas flow velocity, discharge voltage, etc. On T-3M and T-11M tokamaks boronization with carborane yielded a B/C film ratio of 2-4.

Structural analysis by electron microscopy have shown that the coatings produced by boronization are amorphous and consist of at least two phases. At B/C=1-1.5, they consist of approximately equal quantities of domains (average dimension of 1-3 nm), similar to B_4C and carbon domains having a diamond-like structure. The higher the B/C ratio, the greater the quantity of the B4C phase, and at B/C=4, the boron carbide phase dominates.

Erosion of boron-carbon films arising from contact with a D2 plasma is more than one order of magnitude lower than that of graphite materials.This erosion yield is independent of temperature in the 100-550° range, and on boron-carbon ratio in the 1.6-2.5 range. Erosion under these conditions is considered to be chemical in nature. Porosity is believed to play a substantial role by providing additional surface area subject to erosion by thermal atoms. When the surface was subjected to only a thermal atom flux, the erosion yield increased by an order of magnitude and was comparable to that of boron-doped graphite USB-15 (15% boron

content). The presence of D+ ions was assumed to smooth the surface topology and thus restrict access to inner pores, resulting in the lower erosion yield noted above.

Hydrogen isotope recycling, that is the number of hydrogen isotope atoms released from the wall devided by the number of impinging hydrogen isotope atoms, plays an important role in the performance of fusion devices. Its reduction has been considered to be a key factor in improving particle control by means of a gas feed or pellet injection, and for achieving good plasma confinement. The recycling depends both on factors intrinsic to the wall, such as wall material and surface condition, and on external factors, such as hydrogen concentration in the wall, wall temperature, impinging flux, etc. But the fraction of recycling dependent on the wall material itself is lower for a-B/C:H films than for carbon. This is associated with the ability of a boron-containing film to more effectively retain hydrogen isotopes, as compared to carbon. In deuterium experiments, an additional problem arises from the hydrogen dilution of a deuterium discharge. This isotope exchange is impossible when deuterated boron-containing precursors, such as deuterated carborane is used. However, the recycling behavior of a boron-containing film, discussed above, plays a positive role in hydrogen/deuterium exchange, since enhanced hydrogen isotope retention reduces the hydrogen release responsible for diluting the deuterium plasma.

One of the advantages of boron-containing coatings compared to carbon-only films is its capability to provide oxygen gettering. As energetic oxygen interacts with boron/carbon materials, CO and, in lesser amounts, CO_2 are re-emitted. Boron oxides are also re-emitted (due to sputtering), but their contribution amounts to only a few percent. Retained oxygen is contained in the form of nonvolatile boron oxides BO, BO_2, B_2O_2, and B_2O_3, probably in the form of complexes B-C-O and as physically trapped CO and O_2. The reaction yield of the emitted CO and CO_2 decreases and the saturated retention of oxygen increases with increasing boron content. Oxygen can also be trapped during film deposition when carbidic states are formed. This mechanism can contribute to the cleaning effect which may occur during the boronization process. The interaction of boron-containing films with H_2O is also of importance. Remarkable oxidation is observed when a boron-containing film is simultaneously exposed to H_2O and

irradiated with energetic particles (electron/He+ beam). At the same time, no oxidation is observed when the film is exposed simultaneously to O_2 and the electron/He+ beam. This fact probably explains why a reduction of oxygen in a tokamak occurs if the chamber is not previously baked to remove water vapor.

One of the most radical consequense of application of boron-carbon films is significant decrease of the heavy impurity influx.

. SUMMARY AND CONCLUSIONS

The protection of vacuum vessel wall by PCVD boron-carbon films substantially improves the characteristics of discharges by suppressing oxygen, carbon, and heavy (e.g. Fe, Ni, Cr) impurities and by limiting hydrogen recycling, especially when compared to carbon films or structural materials.

While several boron-containing gases can be used for boronization, it should be noted that several experiments employed nontoxic, non-explosive methacarborane, $C_2B_{10}H_{12}$, which requires no special precautionary handling or specialized safety equipment. In addition to its superior safety aspects, it is also relatively cheap. Now the precursor deuterated methacarborane, $C_2B_{10}D_{12}$ has been successfully produced and used in the boronization of T-11M tokamak.

References.

[1] O.I.Buzhinskij, E.A.Azizov, A.M.Belov, S.A.Grashin et al., " A simple boronization technique for T-3M and T-11M tokamak chambers ", J. Nucl. Mater. 191-194 (1992) 1413.

[2] O.I.Buzhinskij, A.I.Trazhenkov, W.L.Rowan, X.Bonnin and P.D.Hurwitz, " Boronization of the first wall of the Texas Experimental Tokamak (TEXT-U) ", Bull. Am. Phys. Soc. 39 (1994) 1597.

[3] O.I.Buzhinskij, I.A.Kovan, A.I.Trazhenkov, A.P.Chernobai, " Results of T-11M vacuum chamber boronization with the use of deuterated carborane ", Bull. Am. Phys. Soc. 40 (1995) N10.

[4] E.A.Azizov, A.M.Belov, O.I.Buzhinskij, V.I.Dmitriev et al., "Investigations of ion-cyclotron heating in the T-11M tokamak", Fizika Plazmy 20 (1994) 1060 (in Russian).

Name: Oleg Buzhinskij, Ph.Dr.Head og the Laboratory

Address:Line Company Ltd.,Bolhaya Serpukhovskaya 12,Moscow, Russia,113093

Phone: (095) 334-0538, Fax: (095) 230-2900

E-mail: buzh@fly.triniti.troitsk.ru

MODIFIED GRAPHITE AND CARBONIC FIBRE MATERIALS

Oleg Buzhinskij, Vladimir Otrozhenko, Yuri Virgiliev

The choice of materials for first wall screens and limiters of fusion reactors and other plasma facing elements is made as usual after some compromises, based on their sputtering yield and thermal cracking strength under high heat shocks. The preference is given to such materials which have high heat conductivity, strength and low sputtering yield.

One of the main requirements in forming materials for fusion facilities first wall elements consists in decreasing material sputtering, necessary to minimize plasma radiation losses and increase the life time of the most energy- and radiation-stressed vacuum chamber blocks. At present graphite and carbon-graphite materials are widely used in limiters, divertor plates and shields to withstand high thermal and radiation loadings. The effect of strong increase in the sputtering rate under ion irradiation at temperatures higher than 1200K is a characteristic feature of graphites and carbon-graphite materials of the MPG-8, USB-15, BSG types and of their analogues abroad, as well as of carbonic composites. Such a type of radiation-induced erosion under high temperatures makes the

use of these materials rather problematic.

Some varieties of C-C composites - carbonic fibre materials have been chosen as an object of studies, since a controllable volumetric introduction of impurities is possible there. The following materials were used: KUP-VM type on a carbonic fibre base, KM-5415 type based on a carbonic tissue. The specimens of madified materials with controllable volumetric content of titanium and silicon impurities have been produced on the base of these composites.

Surfaces of specimens were irradiated by a normally-incident monochromatic He^+-ion beam with an energy of 20 keV. The beam current density was 0.4-0.8 mA/cm^2, the residual pressure in the vacuum chamber was $(2\text{-}6)\times10^{-5}$Pa. Heating of a specimen was done with the electron gun located at the back-side of a target. Erosion of carbonic materials under ion irradiation at high temperatures was studied by the secondary ion-energy-mass spectrometry technique. The results of studying carbonic and graphite (MPG-8) specimens irradiated by the He^+-ions are given in fig.1.

The common feature of all the materials is that the carbon emission rises ten times under heating from 700K to 1700K, i.e. an anomalously high erosion takes place. The temperature rise enhances this effect. The influence of impurities on the process of radiation erosion of carbonic materials was studied on the KUP-VM, KM-5415, gravimol specimens modified by titanium and silicon.

Study of the KUP-VM type specimens modified by Ti and Si has shown that the material is characterized initially by high carbon emission under irradiation by He^+-ions. This emission

increases with the temperature rise. At T=1800K the erosion coefficient measured by the gravimetric method (weight loss of specimens) is $S_e = 7$ atoms/ion. An intense evaporation of Si-atoms and emission of C-atoms are observed in this case. However, S_e is reduced with increase in the ion irradiation dose at T=1800K. As a result, after 3-4 h ion bombardment at high temperatures we managed to suppress the radiation-accelerated erosion almost completely. The erosion coefficient at T=1800K turns out to be close to the sputtering coefficient for pure graphite at room temperature, $S_e = 3\times10^{-2}$ atoms/ion.

From the results obtained for the KUP-VM +Ti+Si-specimens one can draw a conclusion on the possible mechanism of anomalously high carbon yield suppression under irradiation at high temperatures. An analysis of the surface done with a scanning electron microscope has shown that the observed effect is related to the formation of a strongly-developed microtopography including protruded needles, 2-3 μm long, with a density of 10^9-10^{10} cm^{-2}. The seed centres for such a topographic development are particles of titanium carbide which are probably located at needle points, whereas graphite is placed on the step slopes of the needles and in the valleys among them. Desorption of carbonic atoms from the surface in this case is difficult and it mainly occurs from the phase TiC. Additional feeding of the TiC-phase by carbon is probably performed from both the specimen interior and from the valleys among needles upon the microrelief.

Following these very promising results of investigation on high-temperature erosion of carbonic materials under irradiation, test series of plates were made of the modified

KUP-VM and KM-5415 composites for working elements in the TSP tokamak.

During the last few years, great efforts have been taken to create graphites with best quality for use in the vacuum vessels of tokamak. With this aim, the possible variants of modification of graphites by carbides, titanium, boron have been considered. The doped graphites have durability relative to radiation impact more higher than durability of pure graphite. In this connection we fell that the graphite modified by titanium carbide represented strong interest. The contamination of Ti in the vacuum vessel of thermonuclear devices creates anxiety because of its relatively high atomic weight. As titanium carbide, it has properties that are very important for first wall materials. It has more resistant to thermal shock than boron carbide. The graphites modified by TiC have much higher heat conductivity than those modified by B_4C. Experiments have been carried out with small dispersed graphites RGT. In the RGT samples the doped TiC were varied from 1 to 5 μ. The TiC concentration was about 3.5 at %. The values of heat conductivities for different graphites are show in fig.2. The ion bombardment was carried out in the glow discharge plasma. The samples were exposed He^+-ions (E=800eV, j=1.8mA/cm^2). At heating the samples to temperature T=1600K the mass loss was essential only at first heating. The rate surface sputtering of the RGT graphite during bombardment by He^+-ions (800eV) was low: S_e= 0.11at/ion at 800K and S_e=0.27at/ion at 1650K. This is a less than the rate that was obtained for the MPG-8 graphite at the same conditions: S_e=0.15at/ion and S_e=0.25 at/ion, respectively.The surface transformation was quite different. At 800K the surface cones

were developed. At 1600K the cones were not created and at the surface the carbide particles was seen without observable influence on their form by ion bombardment. It can be only noted that the carbide separation was smoothed. The development of conical structures at the RGT graphite surface is impossible to explain only by accelerated sputtering of graphite between the inclusion of TiC, although part of the conical figure was formed in similar way. Probably, that conics are formed mainly due to diffusion of material in the peak that compensates the sputtering. The diffusion is stimulated by strain appearing at the surface and at the slope conics during the ion bombardment. Redeposited on the graphite Ti atoms are for the development of strain and the conic growing. At 1650K the redeposition atoms of titanium evaporated from the graphite surface and the level of strain necessary to the growing of the conics was not reached. The ionic bombardment at T=800K activates annealing processes of graphite. Doping TiC in graphites accelerates this processes. The important consequence is the transformation of the surface structure.

Conclusions

Modified TiC the RGT graphite with high heat conductivity 500-600W/mk and KUP-VM+Ti+Si with the possibility to depress the radiation-enhanced sublimation effect at the wide temperature interval is a perspective candidate materials for the first wall of tokamaks.

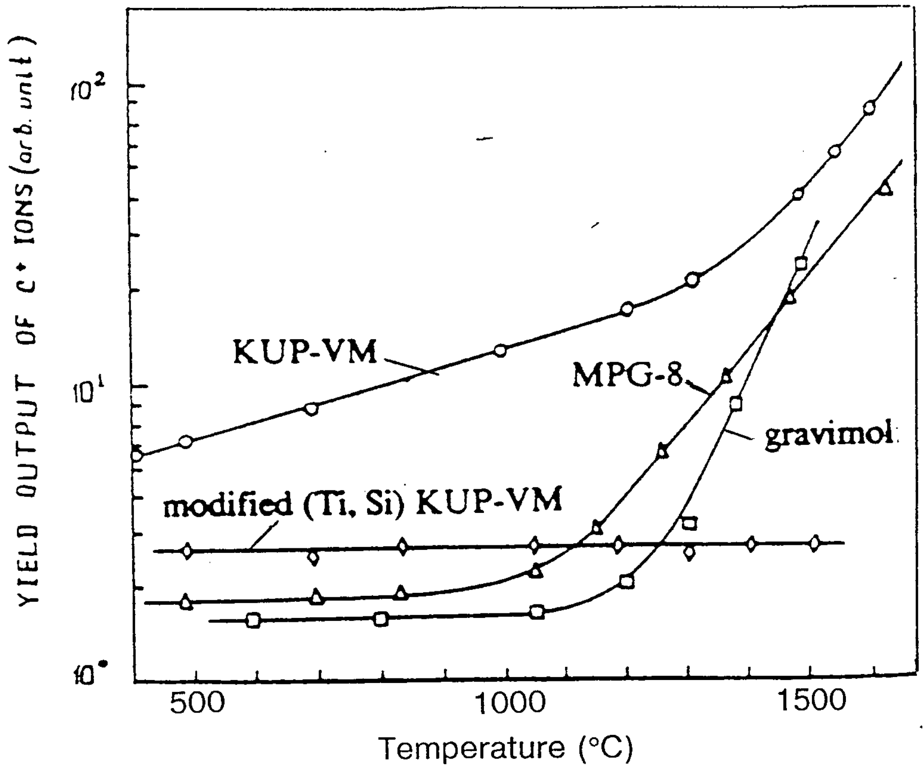


Fig. 1. Temperature dependence of the yield output of C secondary ions with 7 eV energy, emitted from different graphite types under He^+-irradiation, 20 keV.

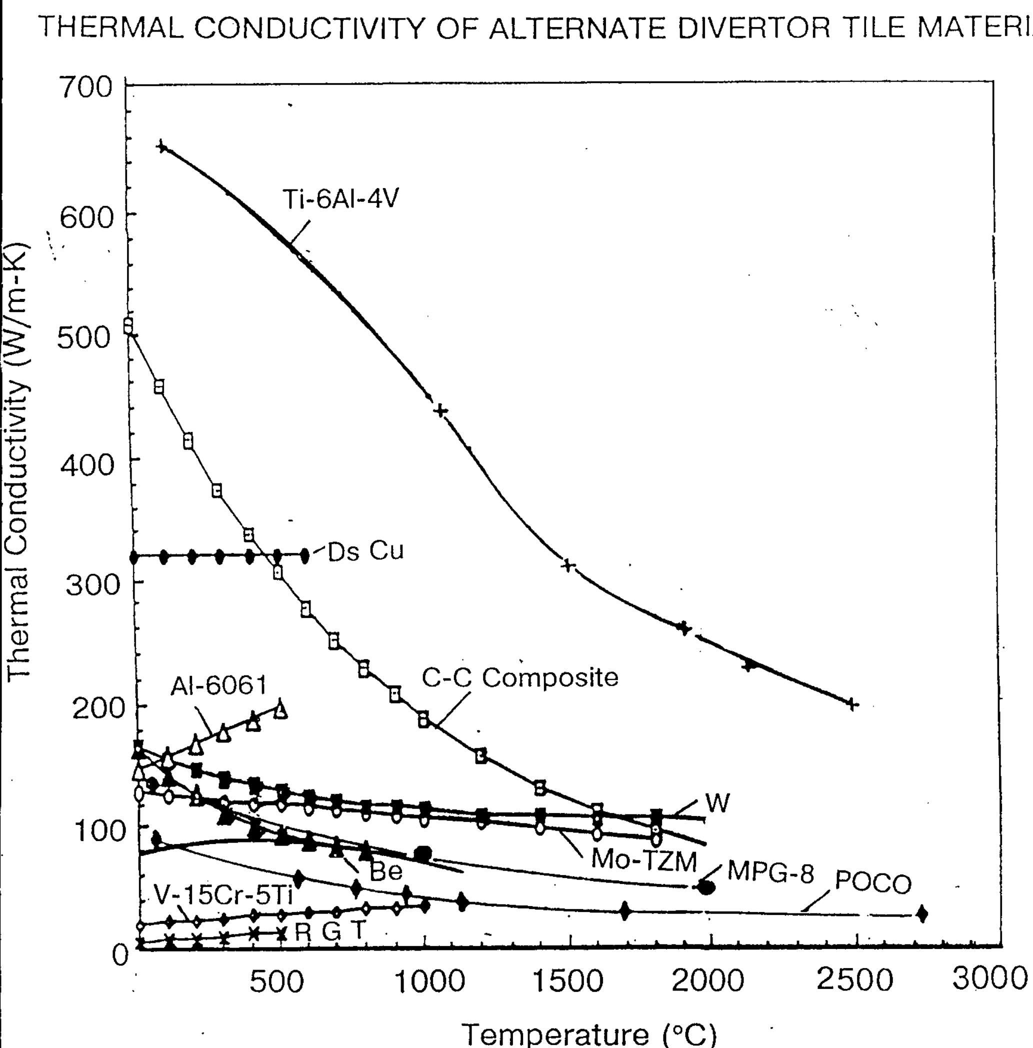


Fig.2.Dependence of heat conductivity of different materials as a function of temperature

Office of Naval Research, Europe
223 Old Marylebone Road
London NW1 5TH

[44](171) 514-4508 fax - 4924
cdorman@onreur.navy.mil
http://www.ehis.navy.mil/

ONREUR Mission

In the interests of the Chief of Naval Research...

Facilitate the exchange of knowledge between the United States scientific and technical community, and their counterparts throughout Europe, Africa and the MiddleEast

Customers

- US S&Es & International colleagues
- ONR POs, Departments, Divisions
- CNO &The Fleet: JCTP, NSAP; initiatives
- NRL, Warfare Centers , Navy University Labs
- Navy SYSCOMS, PEOs/PMs, direct or via NIPO
- Other MILDEP OXRs and Labs, ARPA, NSF
- Other federal agencies: NOAA, NASA, NSTC...
- Federal assessment & analysis communitiues
  - DDR&E, Economic Security, Net Assessment, CRO etc
- Universities & industry consortia

ONREUR Programs

Liaison Visits

Conference Support Program

Visiting Scientist Program

International Cooperative Opportunities in S&T Program

Conference Support Program

- Financial Support for Workshops, Conferences
  - Must have strong Navy interest and program impact
  - Generally excludes major meetings of international or national societies
  - Interaction with ONREUR Scientific Officers essential to determine interest and scope
  - Coordinated with Army and Air Force counterparts
- Conditions: Free of additional cost
  - Recognition of sponsorship
  - Comprehensive written report for ONREUR distribution
  - copies of all meeting materials
  - space and support if ONREUR participates
  - registration for designated number of US participants

ONREUR Liaison Visits

- Discuss science and technology of mutual interest
- Describe US programs, Navy interests
- Compare plans, programmatics
  - Improve coordination and collaboration
  - Mutual benefit and potential savings
- Report to Customers
  - e-mail to US S&T Community; post on Web homepage
  - Objective: influence US research programs, based on opportunities in Europe, Africa and the Middle East

Visiting Scientist Program

- Financial assistance for international scientists and engineers to visit US institutions, sponsors
  - Enable new researchers to establish contacts, develop collaborative proposals
  - Help established researchers to share findings, techniques
  - Support key participants in Navy planning meetings
- Support of US investigators to accompany ONREUR staff to assist in assessments
- Conditions:
  - Generally limited to travel, per diem, registration costs
  - Technical report for ONREUR distribution, and acknowledgement of sponsorship generally required

International Cooperative Opportunities in S&T Program

- Objective: Improve, Expand, and Institutionalize, coordination of Navy's international S&T efforts
- Emphasize new S&T opportunities, and new relationships, to develop mutual understanding
- Three part process:
  - Develop Strategy outlining ONR S&T priorities with linkage to US regional cooperation objectives, and individual country strengths and capabilities
  - Build Knowledge Base of ONR S&T programs and of international S&T facilities/capabilities for improved use of complementary capabilities
  - Cost sharing with US S&T sponsors to encourage participation in high quality international collaborative S&T projects

ICOP Ground Rules

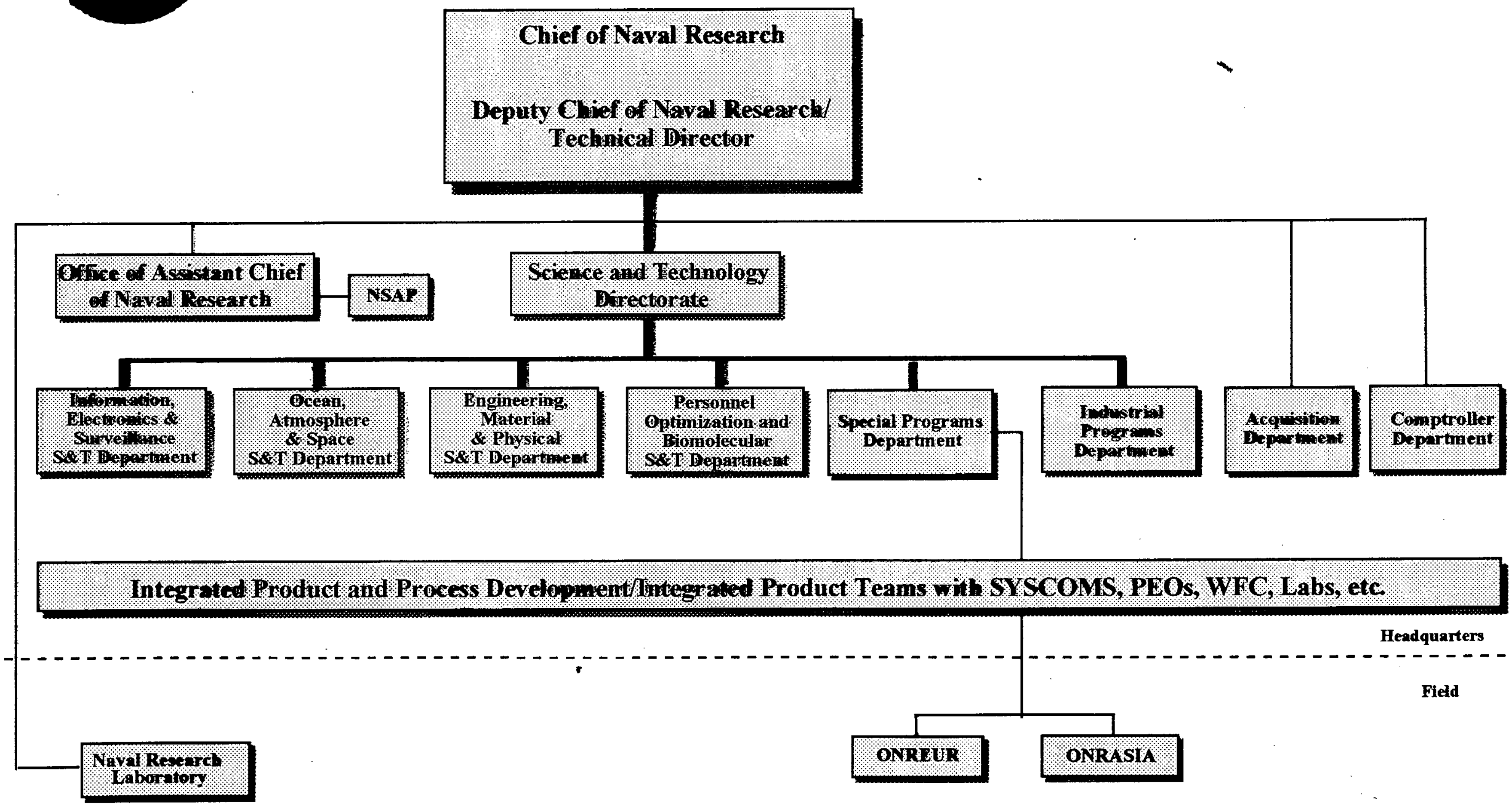
- **Eligibility: Cost shared projects must**
  - Fund non-US investigator at non-US institution
  - Provide for face-to-face exchange of expertise, perspectives among participating US and International researchers
  - Gain at least 50% of project costs from other sponsors
  - Have approval by cognizant ONR Program Officer to maintain coherence of overall Navy S&T program
- **Guidelines:** In addition to technical merit, projects should
  - Support the ONREUR strategy and plans
  - Be new work, and encourage new collaborations
  - Require relatively limited ICOP funding (total =$1M/yr)
  - Be developed in collaboration among ONREUR, ONR PO, Navy Lab/Center, and the International participant and sponsor ("Blind" proposals have little to no chance!)
  - Protect IPR of all parties

ONREUR Resident Staff*

- <u>Biological & Cognitive Sciences</u>: Dr Igor Vodyanoy (ONR)
- <u>Material Sciences</u>: *Dr Ben Wilcox (ARPA)*, DrJack Mecholsky (U. Fl), Ms Julie Christodoulou (Imperial Col)
- <u>Information Science</u>: Dr. Bruce Barnes (NSF), Mr. Otto Kessler (NAWC)
- <u>Environmental Sciences, Littoral Warfare</u>: Dr Ken Lobb (PSU), Dr Craig Dorman (PSU), *Dr Alan Weinstein (ONR), Dr Robert Dolan (U Va), LCDR John Joseph*
- <u>Engineering Sciences, Acoustics, Ship Systems</u>: Dr Peter Majumdar (ONR), *Dr Howard Bunch (U Mich)*
- <u>Surveillance, Strike, & Air Systems</u>: CDR Larry Raithel, Mr Otto Kessler(NAWC)
- <u>Industrial Programs</u>: Mr John Lewis (OGC), *Dr H Bunch (U Mich)*
- <u>S&T Policy</u>: Dr Dorman (DDR&E), *Mr Stuart Schwartsiein (USD-P)*

* *Plus Adjuncts throughout US and Europe*

Office of Naval Research



Strategic S&T Areas

The highest level of program breakdown unique to individual departments by which fiscal and programmatic guidance is issued.

Strategic S&T Areas

Information, Electronics & Surveillance

- Mathematics
- Computers
- Electronics
- Surveillance
- C3
- Electronic Combat
- Modeling & Simulation

Ocean Atmosphere & Space

- Oceanography
- Atmospherics
- Astronomy/Astrophysics & Space
- Undersea Sensor/Surveillance
- Mines/MCM
- Marine Corps

Engineering, Material & Physical

- Physics
- Chemistry
- Environmental Quality
- Materials
- Mechanics
- Energy Conversion & Explosives
- Ships & Submarines
- Undersea Weapons

Personnel Optimization & Biomolecular

- Biological, Health & BW/CW
- Cognitive & Neural Sciences and Human Factors
- Biorobotics
- Personnel & Clothing
- Training & Training Devices
- Logistics/Shore Facilities/Waterfront
- Bioremediation, Biofouling

Special Programs

- Surface/Air Weapons
- Aircraft
- LO/CLO
- EOD/SPECWAR
- Special Programs

Industrial Programs

- SBIR
- MANTECH/MANSCIENCE
- Tech Transfer/IR&D
- Industrial Outreach

ONR Headquarters

- 00: Chief of Naval Research: Radm Marc Pelaez 696-4767
- 01: Deputy CNR/Tech Dir: Dr Fred Saalfeld 696-4517
- 00CC: Corporate Counsel: Mr Elward Saul 696-4271
- 03: S&T Directorate: Dr Arthur Bisson 696-8581
  - Deputy Dir: Dr Bruce Robinson 696-4101
- 02: Acquisition Department: Capt Jay Miller 696-4607
- 08: Comptroller: Mr Thomas Payne 696-4277
- 09: Assistant CNR: Capt R T Scott 696-4261
  - Naval Science Assistance Program: Ms Susan Bales 696-2901

Address: 800 N Quincy St. BT 1, Arlington VA 22217-5660

Phone: US code: 1 Area code: 703

email: *1st-6 last name 1st name initial*@onrhq.onr.navy.mil

Basic Research (6.1) Program Execution

- **Performers:** Universities 52%, Government 32%, Industry 16%
- **Investment Balance:** 60% evolutionary research, 15% high-risk/high-payoff, 25% Fleet applications
- **Emphasis Areas:** 34% Ocean, 14% advanced materials, 10% information sciences, 42% sustaining program
- **Investment Areas:**
  - Ocean Sciences 23%
  - Atmospheric Sciences 6%
  - Biological & Medical Sciences 8%
  - Cognitive & Neural Sciences 4%
  - Physics 10%
  - Chemistry 7%
  - Mathematics 5%
  - Computer Sciences 5%
  - Electronics 12%
  - Materials 9%
  - Mechanics 9%
  - Education 2%

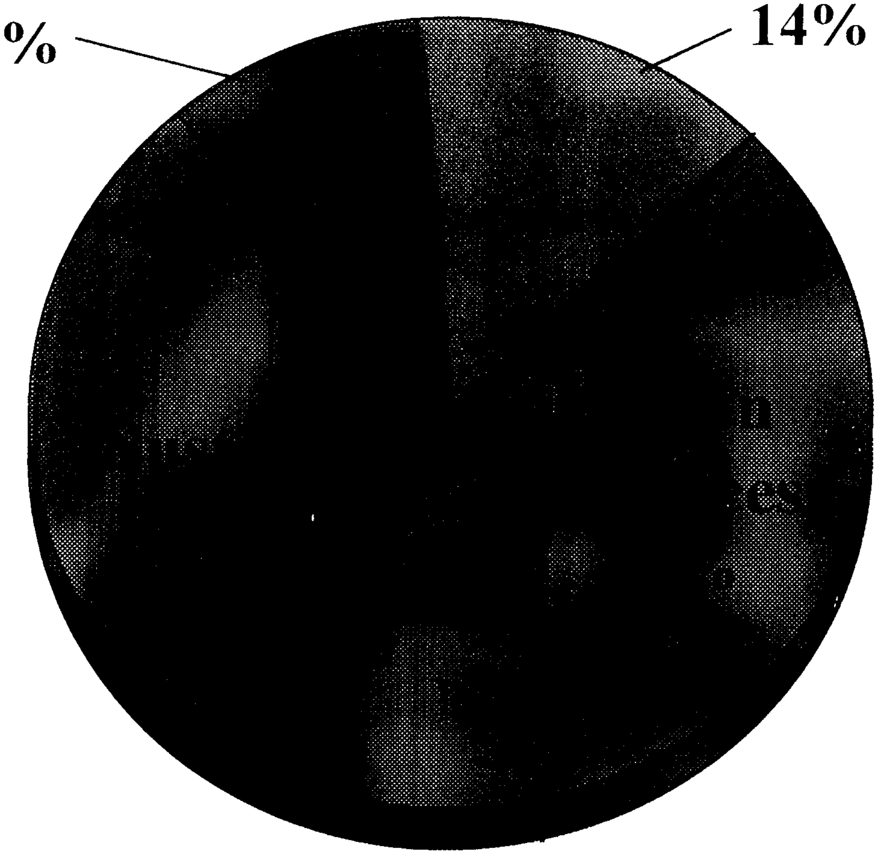
Major 6.1 Initiatives

- Optimal Nonlinear Filtering for Target Tracking
- Electromagnetic Matched Field Processing
- Time Frequency/Time-Scale Analysis
- Volume Visualization
- High Power Devices
- Multiscale Image Processing
- Artifical Color Retina

- Broad Band Laser Modulator
- Quantum Effect Devices for High-Speed Signal Processing Electronics
- Optimal Real-Time Planning
- Fuzzy Logic Control
- Improved Ionosphere Understanding

- Diver held Acoustic Video
- Biosonar
- Biochemistry of Marine Sed iments
- Algal Biotechnology
- Therapeutic Resusci-tation Fluids
- Automated Authoring Tools
- Hybrid Neural Systems
- Biosensors
- Biomaterials

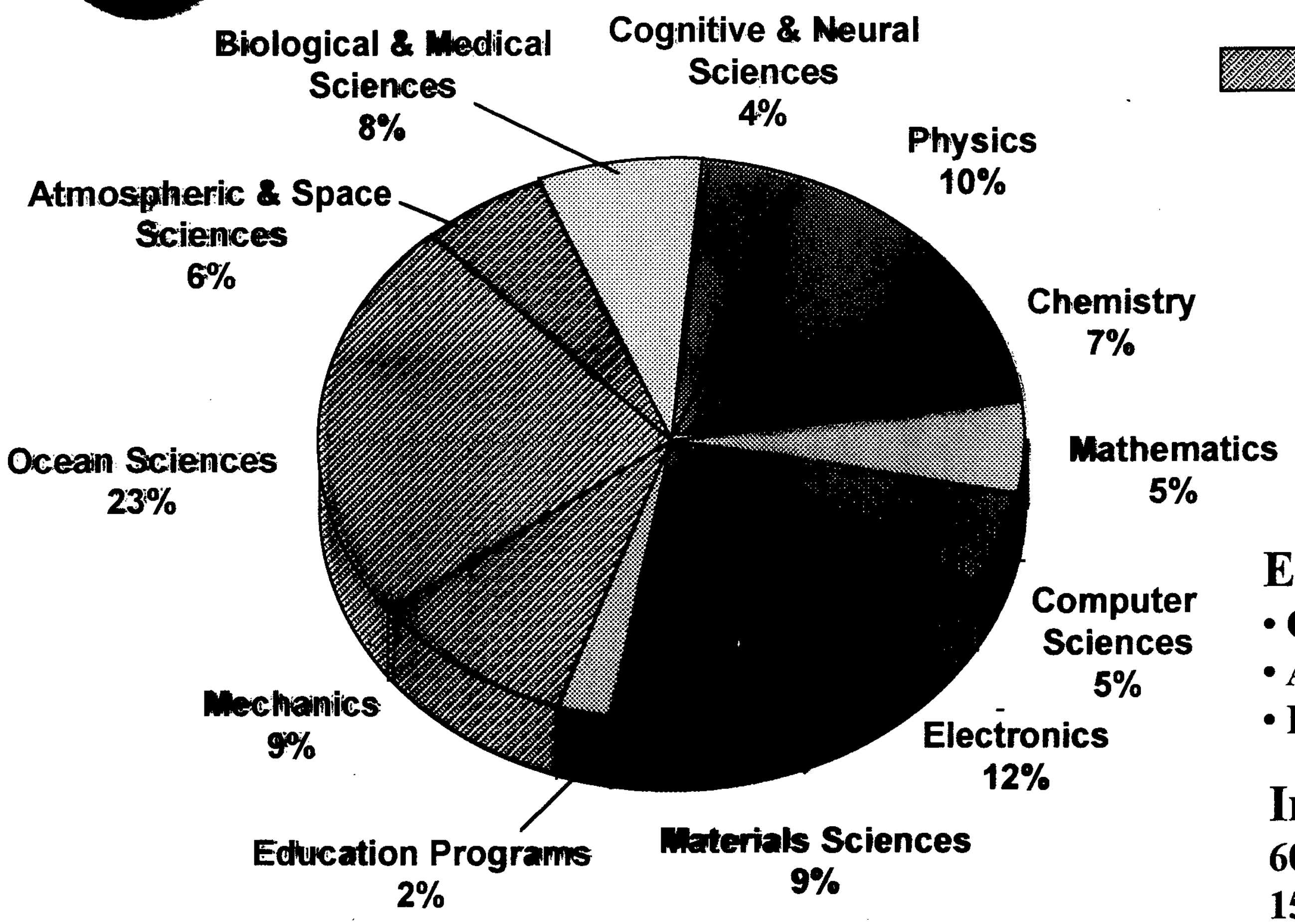
Basic Research (6.1)
FY 96 by Emphasis Areas



Dr. Dorman

Basic Research (6.1) By Discipline

FY 96



FY 96 $402M

Emphasis Areas
- Ocean Sciences
- Advanced Materials
- Information Sciences

Investment
60% Evolutionary
15% High Risk/High Payoff
25% Fleet Applications

EUROPEAN RESEARCH OFFICE (ERO)

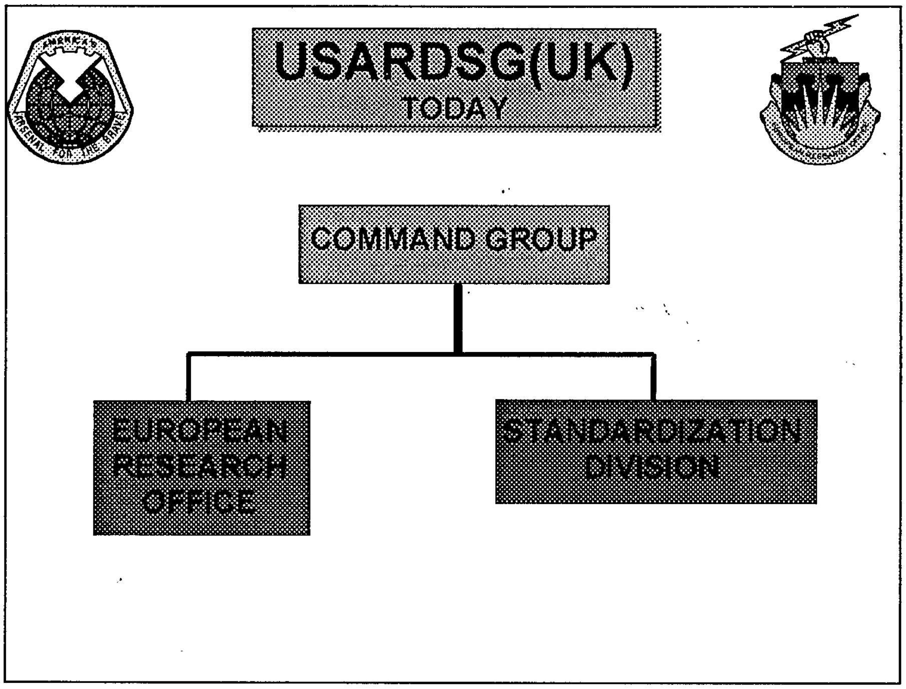
A DIVISION OF THE
U.S. ARMY RDS GROUP IN LONDON, UK

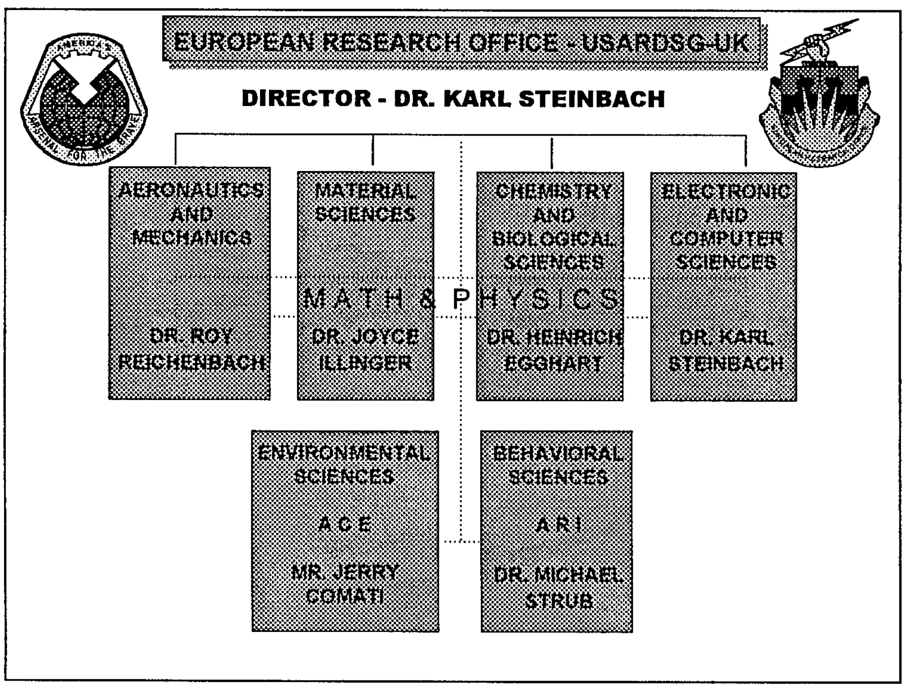
INFORMATION BRIEFING
SEPTEMBER 1996

BY
DR. JOYCE L. ILLINGER

AGENDA

- WHO WE ARE
- WHAT WE DO
- HOW WE DO IT


USARDSG(UK)
TODAY
COMMAND GROUP
EUROPEAN RESEARCH OFFICE
STANDARDIZATION DIVISION


EUROPEAN RESEARCH OFFICE - USARDSG-UK
DIRECTOR - DR. KARL STEINBACH
AERONAUTICS AND MECHANICS
DR. ROY REICHENBACH
MATERIAL SCIENCES
DR. JOYCE ILLINGER
CHEMISTRY AND BIOLOGICAL SCIENCES
DR. HEINRICH EGGHART
ELECTRONIC AND COMPUTER SCIENCES
DR. KARL STEINBACH
MATH & PHYSICS
ENVIRONMENTAL SCIENCES
ACE
MR. JERRY COMATI
BEHAVIORAL SCIENCES
ARI
DR. MICHAEL STRUB

ERO MISSION

TO BUILD INTERNATIONAL
PARTNERSHIPS IN SCIENCE AND TECHNOLOGY
AND INFUSE FOREIGN TECHNOLOGY INTO
U.S. R&D PROGRAMS

EUROPEAN RESEARCH OFFICE (ERO)

AREAS OF OPERATION

* WESTERN EUROPE

* CENTRAL EUROPE AND FSU

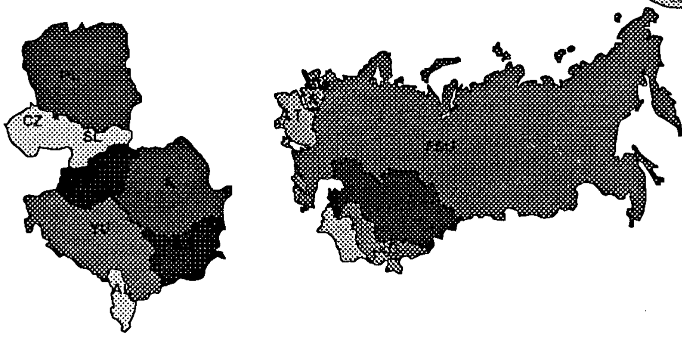
MIDDLE EAST

AFRICA

SOUTHWEST ASIA

* PRIMARY FOCUS

INITIATIVES IN



CENTRAL/EASTERN EUROPE

TECHN. TRANSFER PROCESS

METHODOLOGY

- o UNDERSTAND ARMY NEEDS
- o SEARCH FOR RELEVANT DEVELOPMENTS
- o RECOGNIZE TECHNICAL LEADERS
- o GET THE EXPERTS TOGETHER

ACTIONS

- o LIAISON VISITS
- o WORKSHOPS
- o SEED PROJECTS
- o LONG TERM COLLABORATION

PUBLICATIONS

- o INFORMATION BROCHURE INCLUDING BAA - NEW ISSUE - OCT 95
- o TECHNOLOGY HIGHLIGHTS - ANNUAL REPORT

ERO SEED PROJECTS

SMALL, ONE-YEAR EFFORTS TO EXPLORE INNOVATIVE CONCEPTS AND DEVELOP LONG TERM COLLABORATION BETWEEN FOREIGN INVESTIGATORS AND ARMY LABORATORIES

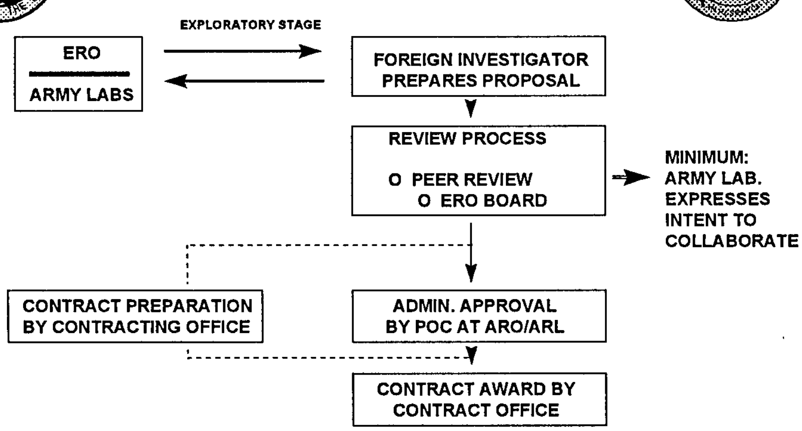
PREREQUISITES

- SPECIFIC TECHNICAL ISSUE OF MUTUAL INTEREST
- ARMY LABORATORY COMMITMENT TO LONG-TERM COLLABORATION IF SUCCESSFUL

MERITS OF SEED PROJECTS

- o SERVES AS INCENTIVE FOR PRINCIPAL INVESTIGATOR TO INTERACT WITH HIS U.S. COUNTERPART (FUTURE FUNDING)
- o EARLY TRANSITION OF TECHNICAL RESPONSIBILITY TO ARMY LABORATORY ASSURES RELEVANCE OF WORK
- o SMALL SCOPE PERMITS RAPID RESPONE TO ARISING OPPORTUNITIES AT LIMITED RISK

SEED PROJECT INITIATION



STATUS OF SEED PROGRAM

PROJECTS INITIATED TO DATE		**55**
FIRST PHASE COMPLETED		**37**
SECOND YEAR FUNDED	21	
CONTINUED COLLABORATION	12	
SUCCESSFUL, PENDING	3	
UNSUCCESSFUL	1	

SUCCESS RATE 89-97%

ERO SEED PROGRAM PROFILE

	FY92	93	94	95	96	TOTAL
PROJECTS INITIATED	5	10	18	13	9 (+5)	55 (+5)
STILL IN 1st PHASE	-	-	-	9	9	18
1st PHASE COMPLETED	5	10	18	4		37
FUNDED BY ARMY LAB	3	6	8	4		21
CONTINUED COLLABORATION	-	4	8	-		12
SUCCESSFUL, PENDING	1	-	2	-		3
UNSUCCESSFUL	1	-	-	-	-	1

ERO SEED PROJECTS BY COUNTRY

NO. OF PROJECTS	COUNTRY
13	FSU
12	UK
6	ISR
6	ITA
5	FRA
3	GEM
3	HUN
2	POL
2	GRE
1	SPA
1	CH
1	AUT
55	

SUMMARY

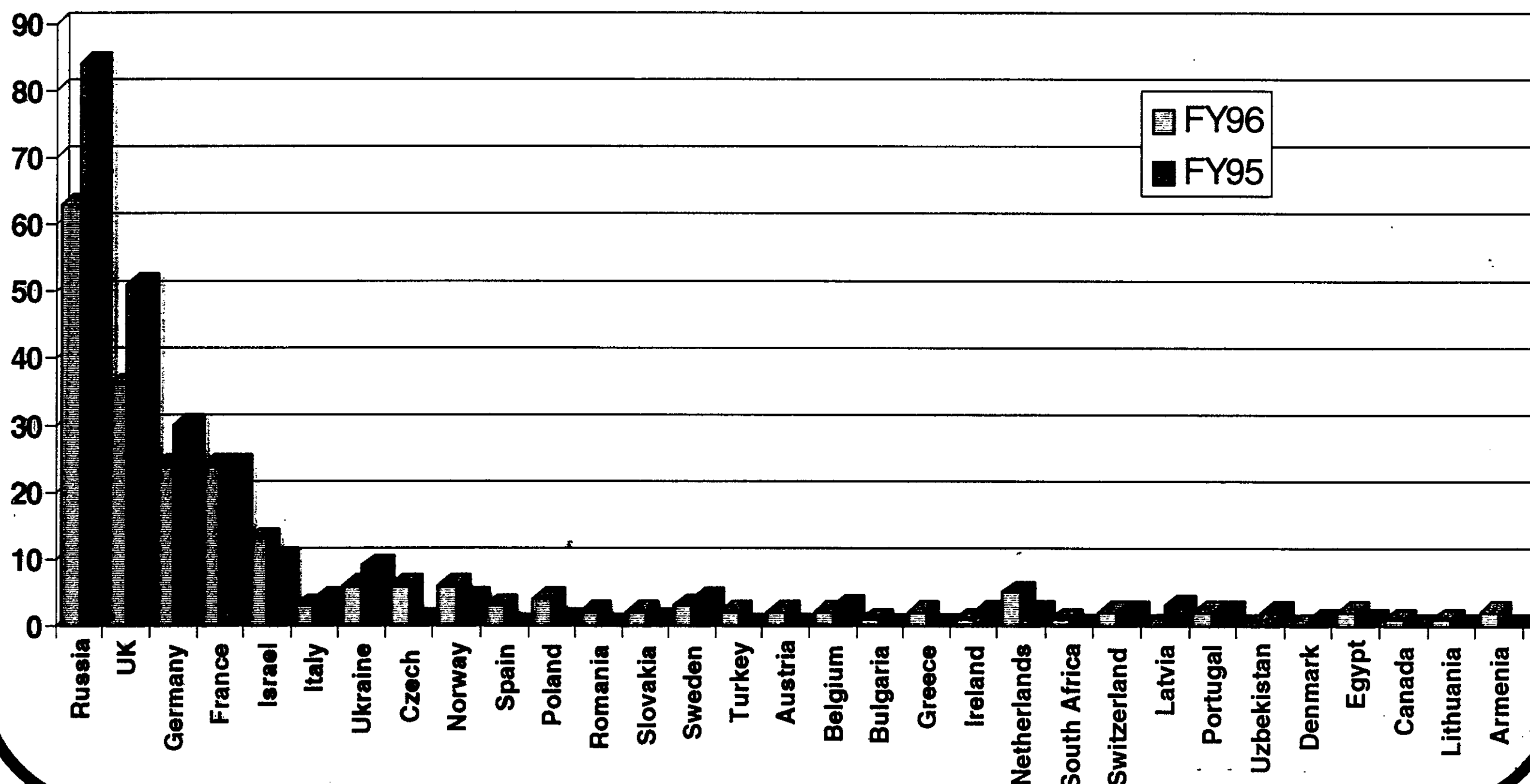
- EMPHASIS ON TECHNOLOGY TRANSFER
- CLOSE TIES WITH RDEC'S, ARL AND ARO
- SEED PROGRAM HIGHLY SUCCESSFUL

Window On Science

- Brings top European/FSU scientists & researchers to DoD labs and research sites
- Typical length of stay 5-7 days
- EOARD provides funding, arranges travel and clearances
- Host lab provides escort

European Office of Aerospace Research and Development

WOS Visits FY96: Countries of Origin



European Office of Aerospace Research and Development

EOARD FY96 Stats

Conference Support: 60 (48 in FY95)

Contracts: 96 (53 in FY95)

WOS Visits: 220 (238 in FY95)

Site Visits: 205 (138 in FY95)

Region-Specific Activity:

RUSSIA

	FY94	FY95	FY96
WOSs			
Number	24	84	63
Total Cost	$37.5K	$123.9K	$182K
Conferences			
Number	2	5	7
Total Cost	$7K	$33K	$32K
Contracts			
Number	64	16	55
Total Cost	$1.47M	$341.2K	$1.32M

European Office of Aerospace Research and Development

Success Stories: DDR&E FSU Contracts Follow-up

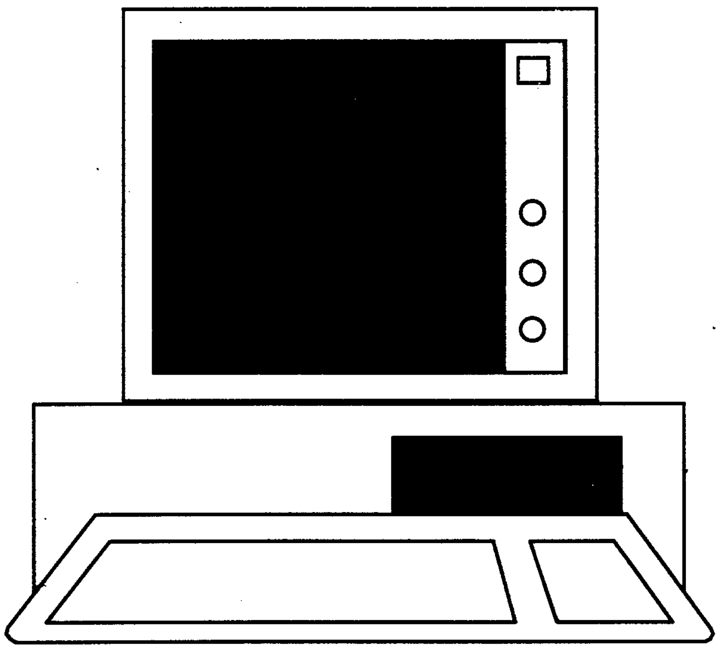
- Protecting Blunt Leading Edges in Hypersonic Flt.
  - Dr. Vasilevsky (TsAGI) $25K + $25K from TsAGI
  - Critical Need for All Hypersonic Air Vehicles
  - WL Estimated Savings at $200-$300K
- New IR Laser Wavelength Conversion Materials
  - Dr. Rud and Bairamov (Ioffe) $25K
  - Comments by WL/MLPO
    - Report Contained Useful New Information
    - Improved Material Nonlinear Optical Properties (Factor of 10)

Success Stories: DDR&E FSU Contracts Follow-up

- Hyperconducting Transformers
  - Dr Demyanov (Institute of Physics & Semiconductors) $25K
  - Transformers Allow Prime Source to Power Several Systems
  - US Spent Several Million Alone on Generator Development
  - No Program to Develop Transformers Existed
  - Uses (and Preserves) Existing Russian Technology
  - US Development Cost Estimated at $5M (USASSDC)
- Additional Results in E-gram Article (Mar-Apr 96)

European Office of Aerospace Research and Development

Products



WWW Homepage

- AF Eurogram
- Navy Assessments
- Army Monthly Newsletters
- FSU Newsletters
- Backgrounds and Missions
- Programs
- Personnel Directory
- European Conferences
- Site Visit Reports

Region-Specific Activity:

Other FSU

	FY94	FY95	FY96
WOSs			
Number	2	14	11
Total Cost	$1.7K	$23K	$29.6K
Conferences			
Number	1	1	3
Total Cost	$5K	$3K	$21.2K
Contracts			
Number	1	3	7
Total Cost	$1.1K	$35K	$71.8K

European Office of Aerospace Research and Development

Research in CIS

$12M FY96-01 AFMC/ST Initiative

- Explosive Pulsed Power
- Helmet Mounted Displays
- Hypersonic and Ramjet Technology
- Lasers and Imaging Technology

Other World Class Technology

- Solid Propellants
- High Power Generation
- Ablation Modelling
- IR Countermeasures using NLO
- Aircraft Aging
- Material Behavior Prediction
- Wind Tunnel Testing Database
- Advanced Machining
- Titanium/Titanium Alloys
- Blast Containment
- CFD
- Vacuum Electronics
- Volume Holography
- Electric Propulsion

European Office of Aerospace Research and Development

Detachment 1

Air Force Office of Scientific Research

EOARD UPDATE
FY96

Col John H. Pletcher, Jr
Commander

Lt Col Don McGillen
Chief Scientist

Smart Materials

Defense Sciences Office

- Sensors/Actuators Can Enable Large Number of Applications
  - Structural/Acoustic Vibration Suppression
  - Embedded Antenna
  - Aerodynamic/Hydrodynamic Flow Control
  - Other Potential Applications Unmined (E.g., "Reactive Armor")
- Key Technical Challenges
  - Materials Development of High Strain Actuators
  - Intrinsically "Smart" Response
    - Chameleon Behavior
    - EM Control

European Office of Aerospace Research and Development

Detachment 1
Air Force Office of Scientific Research

INTRODUCTION to EOARD

Col John H. Pletcher, Jr
Commander

Lt Col Don McGillen
Chief Scientist

European Office of Aerospace Research and Development

Contacting EOARD

Telephone: (44) 171-514-4950 (Voice)
(44) 171-514-4960 (Fax)

E-mail: dmcgillen@eoard.af.mil (Chief Scientist)

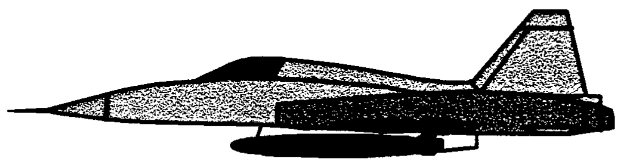
WWW Homepage: http://www.ehis.navy.mil

Agenda

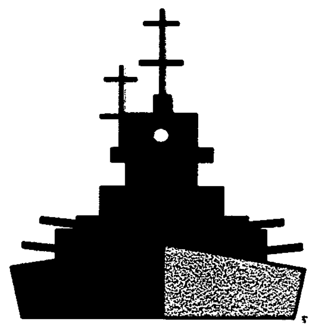
- EOARD Background
- The New Team
- Program Status and Trends:
  - Engineer Scientist Exchange Program
  - Conference Support
  - Special Projects
  - Window on Science
- Success Stories
- Products
- Open Discussion

European Office of Aerospace Research and Development

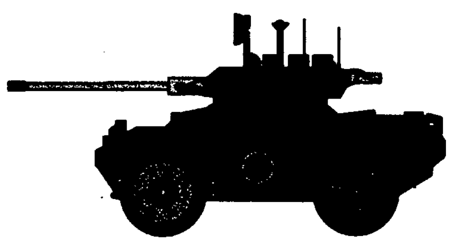
Edison House Organizations



- **Air Force**
  - EOARD
  - R&R Liaison Office London (RDLL)



- **Navy**
  - Office of Naval Research Europe (ONREUR)



- **Army**
  - European Research Office (ERO)

European Office of Aerospace Research and Development

The Mission

AFOSR

Building Partnerships with Relevance and Excellence

EOARD

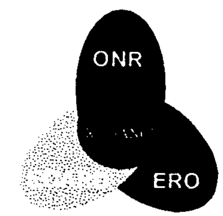
We are your largest S&T organization outside CONUS - In place to build relevant and lasting international partnerships in science and technology.

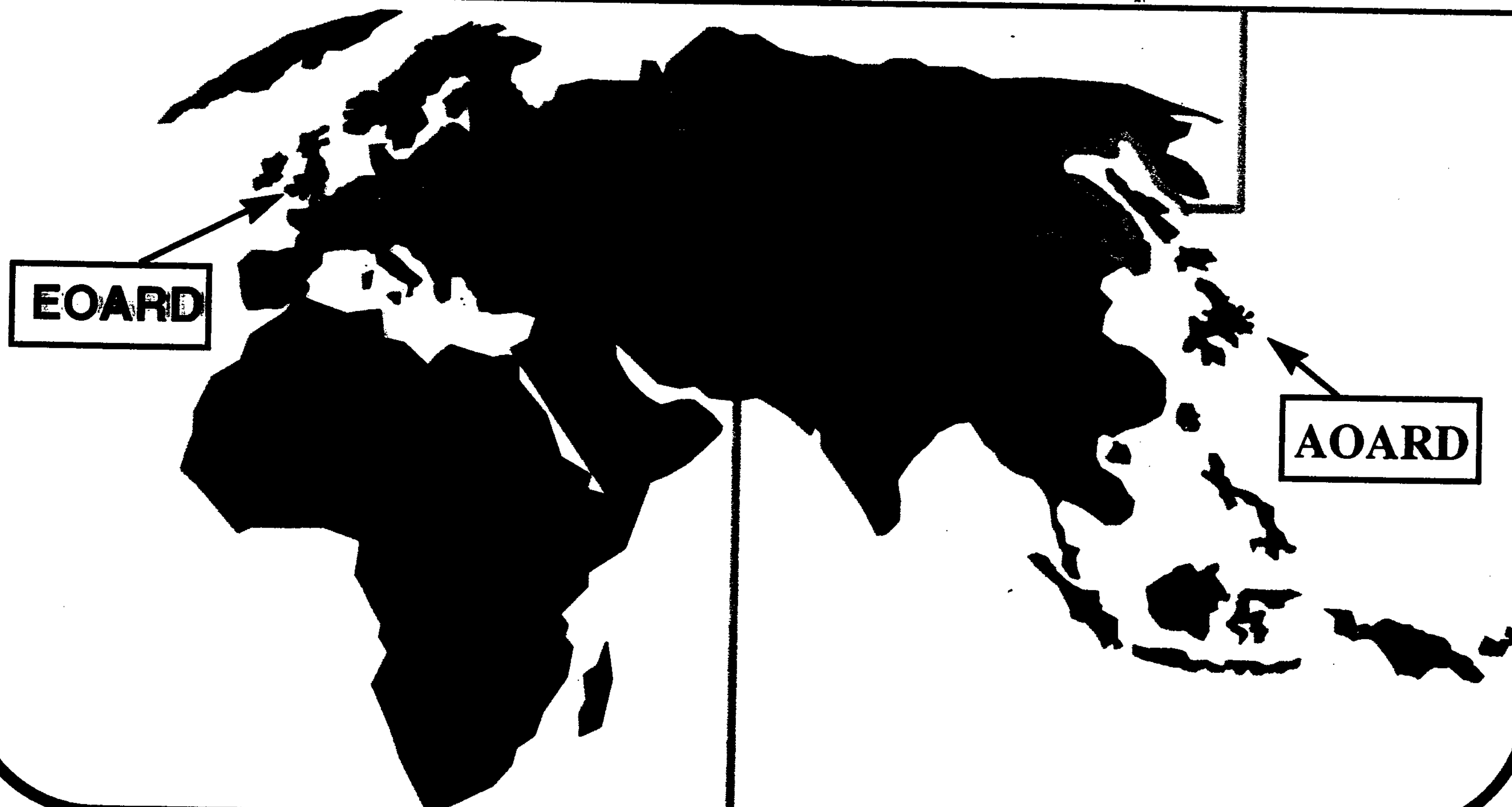
We are Technology Transition Brokers --

- **We put the performer and the customer together**
- **We get involved --help--and move on**
- **We cover a wide area -- Europe, Middle East, FSU, Africa**

European Office of Aerospace Research and Development

EOARD & AOARD Areas of Operation





Primary Customers

- Wright Laboratory - Dayton, Ohio
  Air Vehicles, Aeropropulsion and Power, Avionics, Materials and Materials and Conventional Armament
- Phillips Laboratory - Albuquerque, New Mexico
  Advanced Weapons, Geophysics, Space and Missiles
- Armstrong Laboratory - San Antonio, Texas
  Human Systems
- Rome Laboratory - Rome, New York
  Command, Control and Communication
- Ballistic Missile Defense Office - Washington, D.C.
  Theater Missile Defense, Technology Development

European Office of Aerospace Research and Development

Serving The Customers: The Current Line-up

WRIGHT LAB	Area of Expertise
Maj Jerry Sellers	Structures/Structural Materials
Dr Mark Maurice	Aeronautics
PHILLIPS LAB	
Dr Jack McIver	Laser and Optoelectronics
Dr Kent Miller	Geophysics/Space Sciences
ROME LAB	
Lt Col John Santiago	Electrical and Computer Engineering
Lt Col Don McGillen	Mathematics
ARMSTRONG LAB	
Maj Mark Smith	Biomedical Sciences
BALLISTIC MISSILE DEFENSE OFFICE	
Ms. Vicki Cox	Physics

European Office of Aerospace Research and Development

Our Programs

- *Engineer Scientist Exchange Program (ESEP)*
- *Site Visits*
- *Window on Science (WOS)*
- *Conference and Workshop Support*
- *Contracts*

Site Visits

FY96 Totals:

9 EOARD Scientists visited 205 sites

in 22 countries

Materials and Materials Processing

Structural Materials

Ceramics and Composites

- Ceramic Matrix Composites
- Ceramics Insertion
- Carbon-Carbon
- Personnel Protection
- Solid Freeform Fabrication

Lightweight Metals

- Foamed (ultra-lightweight)
- Low-cost processing of specialty alloys

Functional Materials

"Smart" Materials

- Intrinsic vs. Extrinsic
- Sensors
- Actuators
- Structure Integration

Electromagnetic Materials

- Cryosystems
- Magnetoresistive Materials
- High Density Packaging
- Thermoelectrics

Optical Materials

- Compact Lasers
- Physical Optics
- Holographic Data Storage

Implications for DARPA:

Increased Emphasis On:

- Modeling and Mathematics in Materials Design
- Smart Materials
- Superfunctional (Layered) Materials
- Chem / Bio Specific Sensors
- Wide Band Gap Materials
- Portable Power Systems

New Directions:

- Thermoelectric / Thermophotovoltaic Materials
- Biomimetics / Nanostructures
- Biomolecular Materials / Bio "Interfaces"

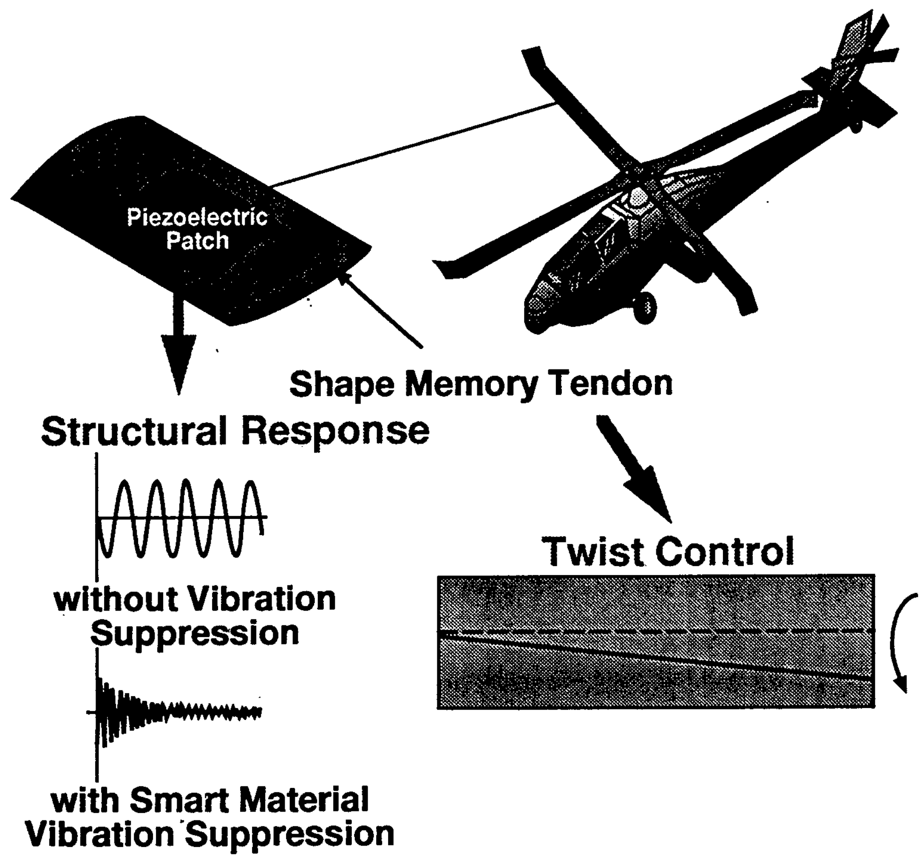
Smart Materials and Structures

Develop a new class of materials that use systems of embedded sensors and actuators to:

- **Sense and constructively respond to their environment with active control**
- **Demonstrate vibration suppression and active tuning -**
  - Machinery
  - Acoustic noise reduction in DoD systems
  - Adaptive shape control
- **System demonstrations -**
  - Military aircraft
  - Submarines

Smart Materials and Structures

Helicopter Blade Vibration Suppression and Twist Control

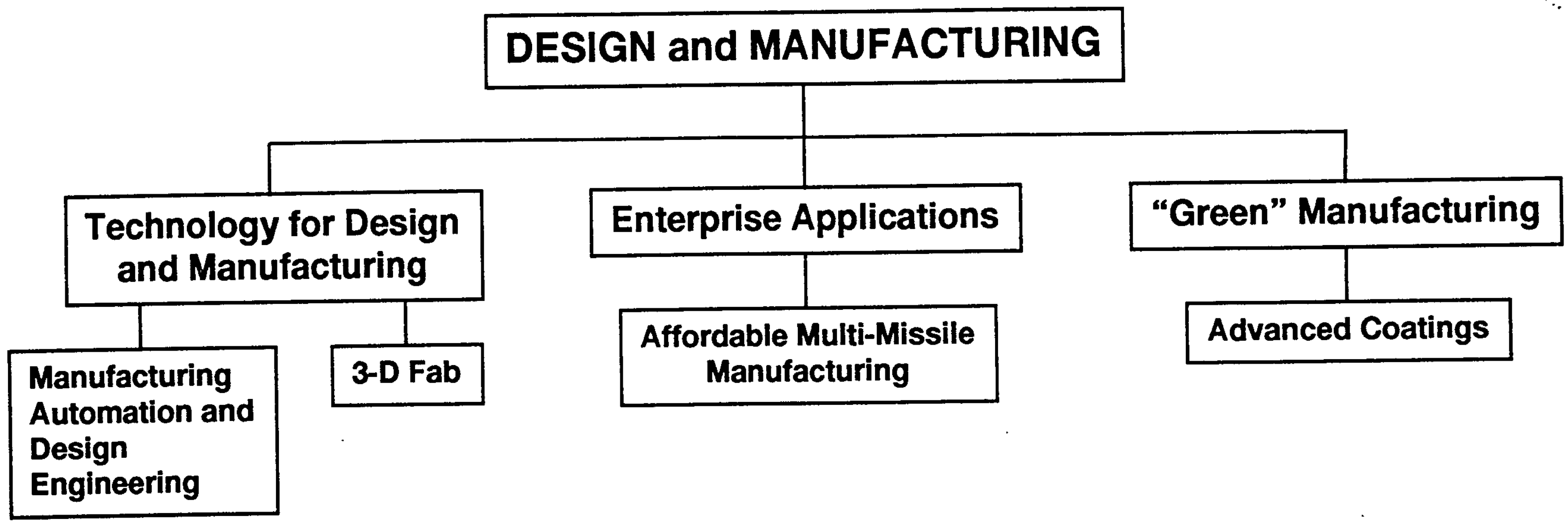


Requirements

- Vibration Suppression:
  - Response: 1-100 Hz
  - Displacement: μm
- Twist Control: (Blade Trimming)
  - Response: Static to 12 Hz
  - Displacement: mm

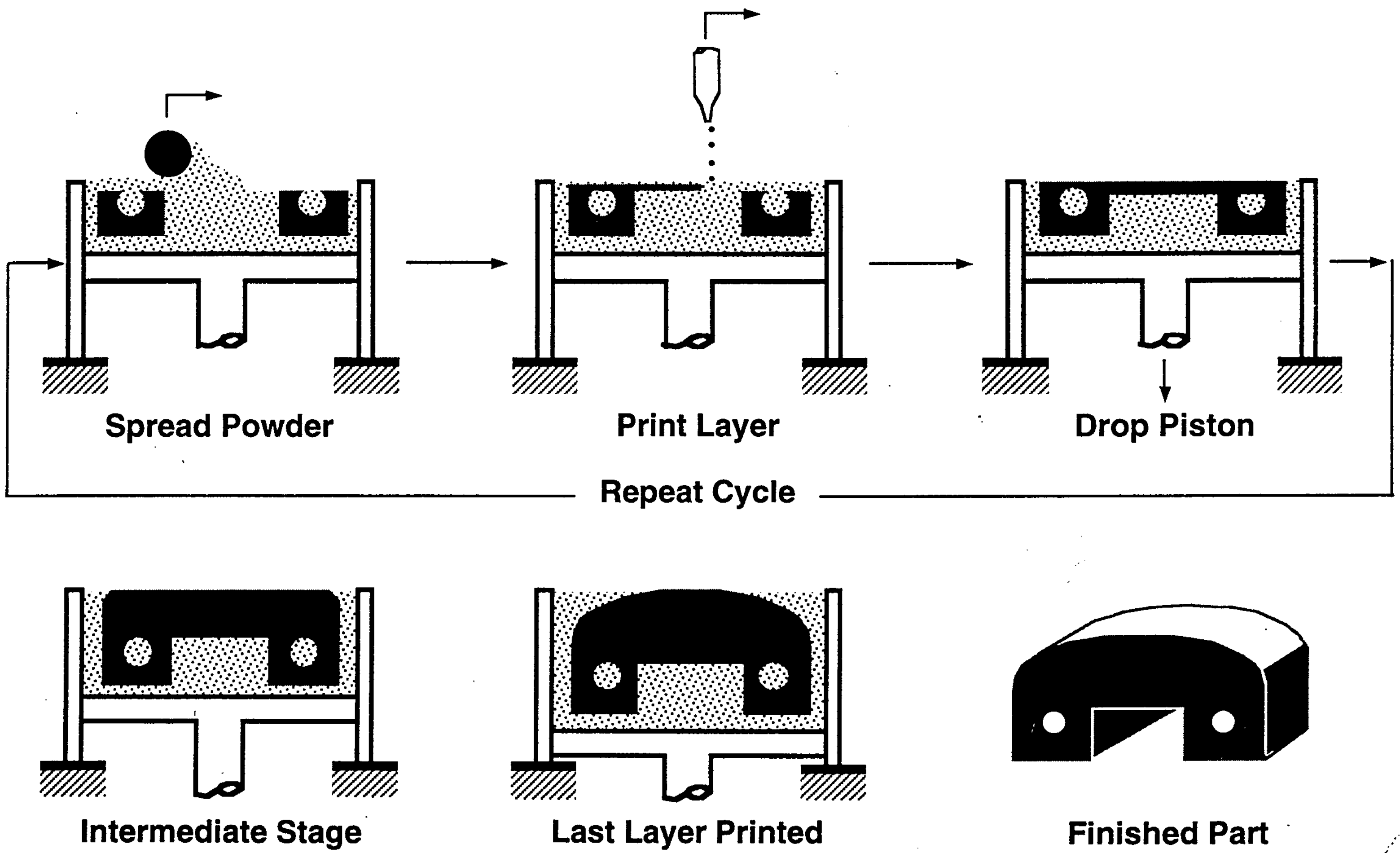
Payoffs

- Increased Speed (from 160 to 200 Knots)
- Increased Readiness of at least 15%
- Increased Range
- Increased Maneuverability



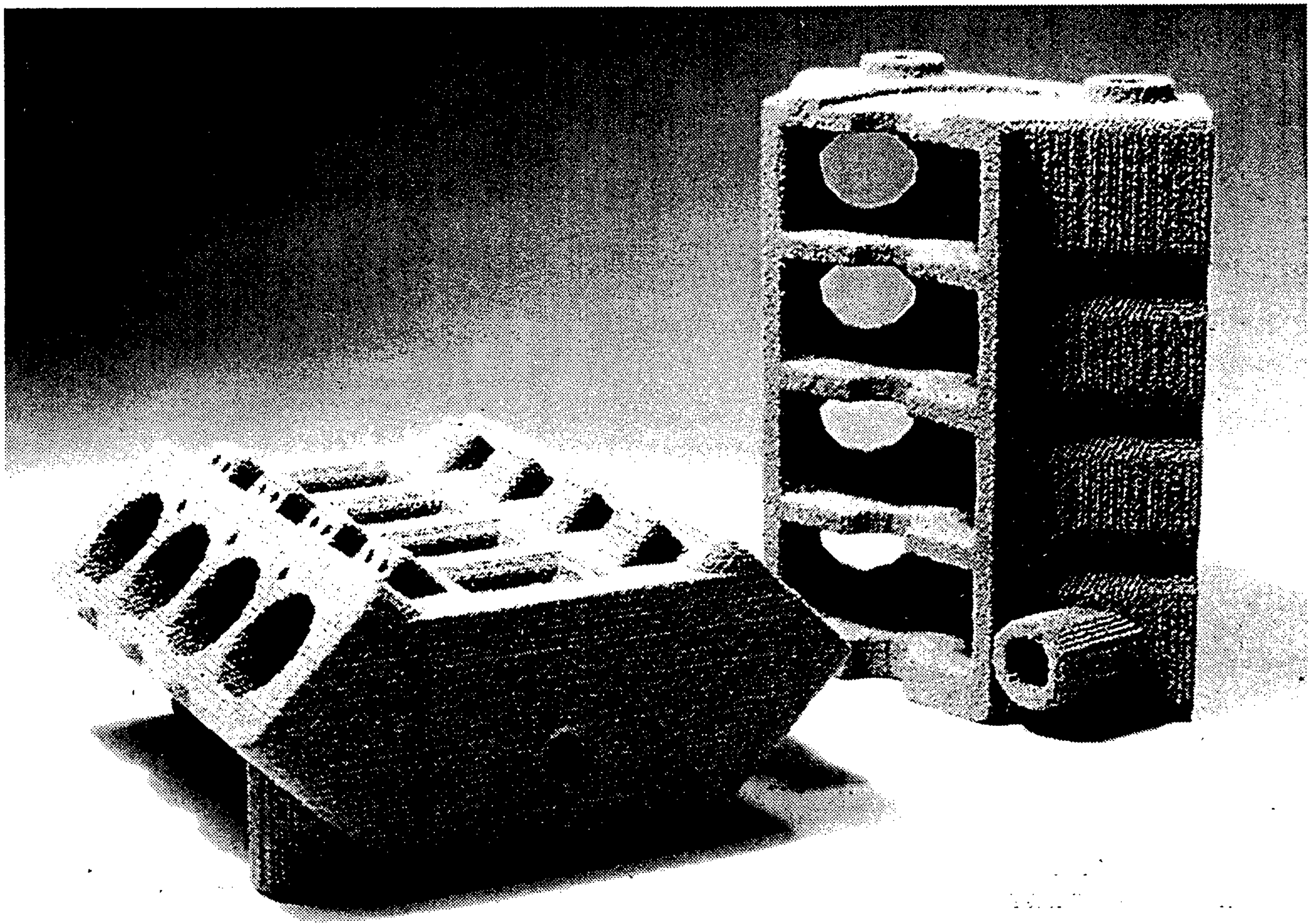
- Develop new representation and design exploration capabilities to rapidly generate and evaluate 10X more alternatives in conceptual design.
- Develop economical fabrication equipment/processes to make rapid prototyping and spare parts on-demand feasible for complex shapes.
- Integrate new design and manufacturing technologies with new business practices, and demonstrate the savings achievable in complex supplier chains by developing and building twice as many missiles within a fixed budget.

Solid Freeform Manufacturing: 3-Dimensional Printing



Defense Sciences Office

Stainless Steel Engine Block: 3-D Printing (MIT)



Protocol

of the final meeting of the participants of the first commercial conference of CIS private companies conducting activity in high-technologies

---

Comments and observations were made by the following people:

Dr. Vodyanoy, *Asociate director USA ONREUR:*

"The current situation in the states of the former USSR is such that private scientific and engineering companies have to unite their efforts to survive The case in point is not one large-scale company, but an association of companies which will create a database of their designs, that will conduct joint marketing activities, and lobby common interests at governmental level institutions and in the mass media.

"There are a lot of such associations in the USA. As a rule, they are united according to the trade principle. For example, there is an Institute of perspective studies in the industry of electromechanics as well as a number of others.

"It is very risky for a foreign customer to deal with a small private company in Russia. An association of such companies like this is quite another thing. In case a problem arises, there is the possibility of re-distributing work inside the association. The association can also afford initiating some large-scale projects on its own. They can be fulfilled in parts. At the same time separate companies, as a rule, are highly specialized

and can not deal with complex projects. That's why I suggest you to consider the unification of your efforts under market conditions.

Dr. A. Gonopolski, *General Director, JSC PLasma-Test:*

"I support Dr. Vodyanoy's idea, but must include one additional idea. Such an association might be not be the only the performer for a reliable customer. The association would receive revenue and then help its members by playing the role of the customer for perspective studies.

Dr. Y. Plotnikov, *Director, Moscow State Technical University named after Bauman:*

"Under the present conditions, even powerful organizations such as Moscow State Technical University with its excellent facilities, power base, and highly qualified staff cannot survive. State finance is insignificant. We can't introduce ourselves into the international market due because we lack sufficient experience. That's why I support the present initiative. We are ready to provide our facilities if they are needed for any large-scale projects taken on by the association.

O. Dudar, *Executive Director SPE Delfin-TTT:*

"We are in favor of the association. We think the idea is very useful and are ready to represent the interests of the association in the Ukraine.

O. Buzhinski, *Lab Head, RF State Research center, Troitsk institute for Innovation & Fusion Research:*

"I support the idea of an association. In the course of work many applied results may appear that can have independent commercial use.

The following representatives spoke:

Dr. F. Vurzel, TOO *Plazmasil*, Moscow,

Dr. V. Poluakov, Moscow High Military Road Engineering College

Dr. Y. Zeldin, NPO *Test* (Ivanovo)

Dr. A.Gonopolski:

"Proceeding from the discussion we can state that all the representatives support the idea of organization an association. It is necessary to develop and register the adequate charter documentation. This is the work that will need concrete people and time taken from the main work.

Who agrees to participate in the preliminary work?

The following candidates were recommended:

Dr. A. Gonopolski A.M.

Dr. A. Vurzel

Dr. E. Azizov

Dr. Puzryakov